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ABSTRACT

Barriers to the implementation of technology-based materials in elementary school mathematics classrooms were studied using naturalistic inquiry and multiple methods of data collection in keeping with ethnographic principles. Qualitative data were gathered from interviews with teachers and administrators, reviews of school documents, observations of classrooms, and analyses of teacher-written responses to open-ended questions. Quantitative data were obtained from classroom observation checklists, lesson and workshop evaluation forms, and two self-report measures of teacher attitudes. The Supplementary Mathematics Materials for a Technological Society (SMMTS) program, which contains calculator and microcomputer activities, was developed to supplement mathematics curricula in grades 1 through 5. The SMMTS develops elementary school mathematics curriculum materials that incorporate technology and studies the effects of these curricula in the classroom. Implementation of the SMMTS was studied in 16 teachers' classrooms in one school district. Major barriers to calculator use were: teacher characteristics; characteristics of the material; and organizational arrangements. Factors that interfered with computer use were: the requirement for computer expertise; difficulties with the equipment; and difficulties with the whole-class demonstration format. The ethnographic techniques offered a valuable perspective on these barriers. One table and three figures present study results. A 26-item list of references is included. (SLD)

# MIXED METHODS IN A STUDY OF IMPLEMENTATION OF TECHNOLOGY-BASED MATERIALS IN THE ELEMENTARY CLASSROOM



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## Introduction

This study determined the extent and nature of implementation of technology-based materials in elementary school mathematics classrooms; more specifically, the extent to which two sets of supplementary mathematics lessons, one utilizing the calculator and one utilizing the computer, were implemented by sixteen elementary school teachers. Ethnographic techniques and philosophy guided data collection and analysis. In keeping with this philosophy or set of principles, the study employed naturalistic inquiry and multiple methods of data collection. A premise of the study was that qualitative and quantitative are not two different research ideologies, but complementary methods which are compatible under a single value system. The guiding principles stated in ethnography are seen to be general research principles important to quantitative and qualitative researchers alike. For example, the principle that measurement should not disturb or alter the system being measured is basic not only to the social sciences, but also in the physical sciences as embodied in the Heisenberg Uncertainty Principle. Patton (1980) states:

> The problem of how the observer affects what is observed is not unique to qualitative research methods. The Heisenberg Uncertainty Principle in physics expresses the same problem from the perspective of natural science. The Heisenberg Uncertainty Principle states that the instruments used to

> measure velocity and position of an electron alter the accuracy of measurement. When the scientist measures the position of an electron, its velocity is changed, and when the focus of measurement is on the velocity, it becomes more difficult to measure accurately the electron's position. The process of *observing* affects what is observed. These are real effects, not just errors of perception or measurement. The situation is changed by the intrusion of the observer. (p. 189)

This principle also guides selection of methods in ethnography. As McKerrow (1991) points out, the naturalistic research paradigm suggests that inquiry must be conducted without interference or manipulation of the research setting and that qualitative designs are often best suited to minimize interference.

The premise of this study is that qualitative and quantitative approaches are not opposites, but different aspects of the same research philosophy and should be treated accordingly. Although traditionally ethnographic data have been almost entirely qualitative, this need not be the case. The present study tended to be from a quantitative perspective, but employed both quantitative and qualitative methods. Unlike most ethnographic studies, quantitative data collection as well as quantitative analysis played an important role in the overall findings of the study. Nevertheless, the qualitative data emerged as the most useful to the study, providing both depth of information and validating the quantitative instruments. In contrast in the analysis stage, qualitative and quantitative methods were found to be equally strong contributors. Qualitative analysis predominated early on, giving way to quantitative methods as the study progressed. The qualitative data and analysis "opened up" many areas which were then confirmed or elaborated upon by quantitative procedures.

Motivation for using mixed methods came from several sources. The first concern is that traditional ethnography requires a great deal of time and labor, much more than many studies require or can afford. The second concern is that the single most important contributor to threats of internal validity when using qualitative methods is thought to be subjectivity of the researcher, sometimes called the "observer effect" (Bogdan & Biklen, 1982). This weakness in qualitative procedures calls for the use of quantitative methods, which may have its problems, but does eliminate the observer effect and researcher bias.

The questions here raised are: How much of the traditional ethnographical method can be dispensed without losing the benefits of the qualitative component, and which quantitative methods should be brought in to supplement this? What are the strengths and weaknesses of each method? Clearly, the goal is to utilize a combination of methods to maximize the strengths and minimize the weaknesses of each method.

In sum, this study used the principles and value system of ethnography as an overall guide. Under the umbrella of ethnography, a mixed method paradigm compatible with the goals of the study was utilized. While this study utilized naturalistic inquiry exclusively, it employed a blend of qualitative and quantitative measures, bringing in more quantitative procedures than is ordinarily found in ethnographic inquiry. In particular, qualitative data were gathered from informal and in-depth interviews of teachers and administrators, informal classroom observations, school documents, and teacher-written responses to open-ended questions on questionnaires. Quantitative data were obtained from classroom observation checklists, Lesson Evaluation Forms (LEFs), Workshop Evaluation Forms (WEFs), and two self-report measures of teacher feelings, attitudes, and concerns. The last two were a Self-Evaluation Questionnaire (adapted from Spielberger, 1977) and "Stages of Concern Questionnaire" (Hall, George, & Rutherford, 1977)

Data collected from formal and informal interviews opened up areas of inquiry, promoted a rapport with participants, provided in-depth contextual information, and provided information to formulate analytic questions. Observational data provided context information, confirmed or contradicted teacher verbal reports, and provided a basis to create the observation checklists. The observation checklists, together with general observational information, provided a measure of the match of teacher behaviors to expected innovation behaviors. Information obtained from other observers supplemented the researcher's observations, thus providing a check for researcher bias. The five quantitative measures listed provided quick, uniform, and easy to analyze data. Qualitative procedures during data collection consisted of an interactive relationship between data collection and analysis which included keeping a log in which strategies, hunches and themes were recorded; testing of hunches;

triangulation; alternative hypothesis testing; and the isolation of key events. Qualitative analysis after data collection consisted of making data displays in the form of tables, matrices or diagrams. On the quantitative side, analyses included formulation of statistical hypotheses regarding linear relationships and correlations as well as developing mathematical models to explain the data.

It had been anticipated at the beginning of the study that the quantitative measures would be used to validate the more subjective qualitative measures. In fact, however, the reverse occurred. The qualitative measures, in a triangulation context, validated or discredited certain quantitative instruments, namely those which measured teacher anxiety and concern, and those which assessed the number of lessons completed. In particular, it was found that the Spielberger Self-Evaluation Questionnaire did not validly assess feelings and attitudes of the teachers in this study. Perhaps the paper questionnaire was more intimidating to teachers in this setting than in other settings where it has been used. Teachers may have perceived the questionnaire as a statement of incompetence that could be put into their files and become professionally damaging, whereas talking to someone was not as formidable a disclosure. Furthermore, the data from interviews and observations served to calibrate the self-report forms, particularly the Lesson Evaluation Forms which asked teachers to report on the extent and nature of the implementation for each lesson. Knowing what a certain teacher said or did in specific instances, helped the researcher understand the context of the responses on the LEFs. Thus the qualitative data provided the researcher with a baseline from which to interpret each teacher's responses. And finally, the widely accepted "Stages of Concern Questionnaire" was found not to tap the specific concerns of this group of teachers regarding these particular innovations. As a consequence, the qualitative methods showed this questionnaire to be of little value in this context. Interview and observational data provided far more pertinent information to the study. Not only did the qualitative techniques eliminate particular quantitative instruments which a priori had seemed to be clear and direct tools of measurement, but these findings also affected the subsequent use of other contemplated quantitative instruments. In contrast to the weakness of the quantitative *instruments* to tap information validly, quantitative *analysis*, on the other hand, provided a strong counterpart to the qualitative interpretation of the data.

It was found that not only did each method provide its own strength to broaden the study, but in some cases there was a blend of both. For example, the numerical index of implementation is the product of the qualitative and quantitative components of implementation. Although neither component by itself was particularly informative, the product afforded more insight into the nature and extent of implementation.

## A Description of the Study

Before elaborating on the methods used, we give some study background. In recent years it has been noted that although computers and calculators are pervasive in our society, there has been a reluctance by teachers and administrators to put this technology into use in the mathematics classroom (Becker, 1987; Hambree & Dessart, 1986; Leinwand, 1985; Suydam, 1982). One may postulate a number of reasons to explain this reluctance, e.g., lack of meaningful technology-based materials which can be integrated into accepted mathematics curricula, lack of appreciation for the worth of these technological tools with regard to the main objectives of the mathematics program, lack of teacher training and guidance, or lack of effective implementation procedures.

In an attempt to promote progress in this area of curriculum development, the National Science Foundation (NSF) awarded grants in 1986 to five universities in the U.S. for projects that would promote the use of technology in the elementary school mathematics curriculum. One such project, herein referred to as SMMTS (Supplementary Mathematics Materials for a Technological Society), was designed to develop elementary mathematics curricular materials which incorporate technology and to study the effects of these curricula in the classroom. The SMMTS materials contain calculator (Willoughby, 1986) and microcomputer (Goldberg and Sgroi, 1986) activities to supplement the mathematics curriculum in the first through fifth grade. This set of materials assumes students have universal access to calculators and easy access to computers. The SMMTS program aimed at changing the students' attitudes toward using technology in the mathematics classroom and changing the methods used in mathematics education. For a detailed description of this program and a report of its effectiveness, the reader is referred to Russek (1991) and Willoughby & Weinberg (1991).

An ultimate evaluation goal of the project was to determine the effectiveness of the program. Before this question could be addressed, however, it was first necessary to know how and to what extent the program was actually being implemented. The present research focused on that implementation process. More specifically, this investigation examined what happened at the classroom level when the SMMTS materials, which require use of the microcomputer or calculator, were introduced into elementary school mathematics. To what extent were teachers using these materials in their classrooms? What were the factors that promoted or hindered their use? Because the adoption and implementation of such materials represented an instance of an educational innovation, the conceptual framework for the study includes concepts from innovation theory.

The SMMTS project also provided an opportunity to examine whether the nature of the innovation influenced the extent of implementation. By looking at two different innovations in the same setting, the microcomputer and the calculator, it was possible to investigate differences in use due to differences in innovation (e.g., availability of equipment and level of technological complexity). Teachers in grades one and two used only calculators, whereas the teachers in grades three to five used both computers and calculators.

## Ethnographic Principles

This study used ethnographic research methods and values. An *Ethnography* can be defined as an in-depth analytical description of an intact cultural scene (Borg & Gall, 1983). The main characteristic of ethnography is that the researcher uses continuous observation, trying to record virtually everything that occurs in the setting being studied. The main elements of the value system are:

a. Phenomenology: which requires the researcher to develop the perspectives of the group being studied, that is, to develop the "insider's" viewpoint.

b. Holism: emphasis on attempting to perceive the big picture rather than focusing upon a few elements within a complex situation.

c. Nonjudgmental orientation: since judgments, hypotheses, or preconceptions may distort what the researcher sees, the emphasis is on recording the total situation without superimposing one's own value system. With this in mind, researchers do not start with specific hypotheses. They may start with a theoretical framework or with tentative working hypotheses that provide general guidelines to the observer about what behavior may be important. In this study notions from innovation theory and learning theory were used to formulate the original thrust and research questions.

d. Contextualism: requires that all data be considered only in the context of the environment in which it was gathered (Borg and Gall, pp 492-493).

There are several techniques of inquiry that have been established to assure that these values are upheld. They are naturalistic inquiry, the use of the role of the researcher as a participant observer, and multiple methods of data collection and analysis. Ethnography permits quantitative methods, as long as they do not contradict the basic research principles. One of the methods used in ethnographic inquiry to obtain an insider's viewpoint and to reduce observer effects is that of participant observer. In this study the first author functioned primarily as an observer, participating enough to gain rapport with the group and taking limited part in activities, but being primarily an observer rather than a participant.

The major criticism of the qualitative approach is that it may lack validity primarily because the researcher is the sole or primary instrument of measurement (Bogdan & Biklin, 1982; Borg & Gall, 1983; Leithwood & Montgomery, 1987; King, Morris & FitzGibbon, 1987). The following set of criteria or strategies was used to judge/provide the validity of this study, which employs a participant observation (Smith, 1978).

*Quality of Direct On-Site Observation and Face-to-Face Interviews*. People often 'mask' from the researcher what is really going on. Masking is much more difficult with a participant observer present than when data collection lies on written questionnaires. As such the use a participant observer was seen as a strength in this study.

*Freedom of Access.* Although the researcher had freedom of access, because of the nature of the SMMTS program, she had to make appointments. Therefore, teachers did prepare for the researcher's visits and a "normal, unbiased picture of what was going on" may not always have been presented. This situation was considered a weakness of the study, mitigated somewhat by the intensity of observation.

*Intensity of Observation.* "As the amount of direct observation increases, the chances improve of obtaining a valid and credible picture of the phenomena being studied" (Borg & Gall, 1983, p. 491), the likelihood of "faking" or "putting on an act" is decreased. In this study, the entire cycle of a school year was observed, which should give as valid a picture as can be obtained. Furthermore, observing the entire cycle of the school year helped gain a complete picture. For example, had observations been done only in May, a number of developments would have been missed, such as the reactions to the lateness of materials distributed in the fall, and the tension between other school commitments and the SMMTS project. This is seen as a strength in this study.

*Triangulation and Multimethods.* This refers to the strategy of using several different kinds of data, such as questionnaire forms, direct observation, interview, other observers, administrator reports, school documents as well as content analysis and statistical procedures (e.g. correlations). The use of triangulation and multimethods is considered to be an important strength of the study.

*Sampling of Data.* After an exploratory phase of the setting, a sampling plan was developed. In this study an attempt was made to get a representative sample of the total data universe by purposeful sampling, as suggested by Patton (1987). In this study the unit of sampling was the teacher. In attempt to achieve diversity, in the face of a necessarily small sample, teachers were selected purposefully from different sites and different grade levels. The final sample consisted of sixteen teachers.

*Unobtrusive Measures.* In the role of participant observer, the researcher noted unobtrusive cues that provided insight into the behavior being observed. For example, many teachers did not let the SMMTS staff know when they were going to present a technology lesson. Noting this behavior, the researcher questioned: Why are they doing this? Was it because they were concerned with their professional image and wanted to wait until they had mastered the materials before allowing observations?

All of the above strategies were important to the validity of the study. Perhaps the most interesting are the quality of direct observation/interviews and triangulation. These two strategies provide rich areas of discussion of the strengths and weaknesses of qualitative and quantitative methods and how they can or cannot be merged to strengthen a study.

## Data Collection and Procedures: Triangulation

Consistent with the idea of triangulation, data were collected from field observations; interviews with teachers and administrators; questionnaires; and other observers. The collection of both qualitative and quantitative data provided independent sources of data that add to, confirm or contradict findings.

Most often triangulation is thought to provide corroborative or verificatory indicators of a finding. It is typically perceived to be a strategy for improving the validity of research findings. "...triangulation is supposed to support a finding by showing that independent measures of it agree with it or, at least, don't contradict it" (Miles & Huberman, 1984, p. 234). It is essentially a strategy that aids in the elimination of researcher bias and allows the dismissal of plausible rival explanations such that a truthful proposition about some social phenomenon can be made (Denzin, 1978 as cited by Mathison, 1988). An alternative conception of triangulation offered by Mathison suggests that there are three possible outcomes of using multiple methods and data sources and researchers. The first outcome is that which is commonly assumed to be the goal of triangulation and that is *convergence*. The notion of convergence assumes that data from different sources, methods, and investigators provide evidence that will result in a single proposition about some social phenomenon. This is similar to the conceptions described above. A second and probably more frequently occurring outcome from a triangulation strategy, according to Mathison, is *inconsistency* among the data. The third outcome is *contradiction*. It is possible not only for the data to be inconsistent but to actually be contradictory. Mathison suggests that "the value of triangulation lies in providing evidence such that the researcher can construct explanations of the social phenomena from which they arise" (1988, p.15). A caveat to be mentioned here is that when assessment is from multiple methods, care must be taken to ensure that the different methods of assessment are measuring the same construct, and that a change in method does not also change what is being measured. This was a concern of the researchers in this study.

This study used multiple methods and data sources because it is thought that each method can reveal a different aspect of empirical reality. Most of the data collected did converge to present a consistent overall picture of what was happening. However, there remained a set of inconsistencies to sort out. These inconsistencies came primarily from face-to-face interview and observation data contradicting data furnished on questionnaires. The following examples illustrate triangulation methods used. In the first case described below the data converge, whereas the next two cases demonstrate inconsistencies in the data.

1. Teacher verbal reports provided the primary data for the assessment of the quantitative index of implementation. These

reports were corroborated by what the researcher saw happening in the classroom. Matching the number and the dates of the lessons observed and the number of lessons reported, the researcher determined whether the teacher's report was plausible. The Lesson Evaluation Forms (LEFs) also provided some supporting information, but because the number of returned LEFs was low, the LEFs provided information only on the minimal number of lessons completed. The consistency or convergence of the three sources of data confirmed the validity of the teacher verbal reports as an accurate measure of number of lessons completed. Comparing the percentages of lessons completed reported by the teachers with classroom observation information and the LEFs, it can be seen in Table 1 that there is consistency among the three sources of information. It was therefore assumed that the teacher's verbal reports provided an accurate account of the quantitative degree of implementation of the calculator. The next two cases illustrate the inconsistencies in various data sources.

INSERT TABLE 1 ABOUT HERE

2. This instance occurred early in the study. After the training workshops in September, teachers were asked to fill out Workshop Evaluation Forms. Frequencies of responses from the Workshop Evaluation Forms indicated that the teachers were satisfied that the workshop had prepared them for classroom use of the computer. However, teachers reported in face-to-face

meetings and on the telephone soon after the workshops that they were worried about the difficulties of including these materials in the curriculum. One teacher, in particular, related immediately after the workshop that she and her colleague did not know what "boot up the machine" meant and felt that they needed more knowledge about the hardware and software to begin to feel comfortable. She continued to express fears and anxiety with regard to problems she anticipated using the computer, yet she, like many of the others, answered that everything was "adequate" on the questionnaire.

3. A second inconsistency arose when the researcher sought objective support for a conjecture that teacher capability to perform was associated with teachers' attitudes. Toward that end, a Self-Evaluation Questionnaire adapted from Spielberger (1977) was administered in December to assess the state of anxiety of each participant as he or she worked in the classroom with the calculator or computer. Each teacher was asked to complete the self-evaluation questionnaire, which consists of 20 Likert scale questions that are designed to indicate how the teacher felt about herself or himself when working with each type of technology in the classroom. To reduce the possibility that two distinct aspects of anxiety were being tapped by the two distinct methods of data assessment, the questions that were asked in the face-to-face interviews were constructed to parallel those on the written questionnaire. Interviews and observations provided one set of data regarding which teachers were more

anxious than others and the questionnaires provided a second set of data. Unfortunately the two sets of data bore no relationship to one another. Teachers who voiced deep concerns and who appeared very anxious when observed in the classroom did not in general evaluate themselves as anxious on the written questionnaires.

These inconsistencies in triangulation were a special type, namely, inconsistencies between interview/observation data and questionnaire data. There are several potential explanations for what happened. In both cases the instrument was trying to tap a measure of anxiety, uncertainty, and perhaps, in the minds of the teachers, a measure of professional competence. They appeared to be reluctant to put on paper what they freely revealed verbally. Perhaps the paper questionnaire represented something more permanent to the teachers, a record that could be put into their files and become professionally damaging, whereas talking to someone was not as formidable a disclosure. One might infer, if this were the case, that teachers exercise more caution in completing written self-evaluations than in responding orally to the interviewer; and conversely, the open-ended oral format provided a more comfortable forum in which teachers could respond. These and other possible explanations should be pursued in future research. Because teachers continued both verbally and behaviorally to express their anxiety and discomfort over time to their administrators as well as to the researcher, the data collected from interviews and observations were taken, in this study, to be the more valid of the two. Although questionnaires are easier to administer and analyze, and provide a different source of information, free from researcher bias, they must be used with caution, particularly if the construct to be measured is of a sensitive nature. (Borg & Gall, 1983; Patton, 1980)

## Analysis of Data

The analysis was a mix of qualitative and quantitative techniques. As in all qualitative research design, there was an interactive relationship between data collection and data analysis. At first data collection was open-ended, attempting to record all events, attitudes, and context. After each observation or research session, the researcher rendered a description of the people, activities, conversations and events in a log. As part of such notes, the researcher recorded ideas, strategies, reflections, and hunches as well as noted patterns or themes that emerged. These fieldnotes were the primary qualitative data that formed the basis of the analysis. A sample of the log is provided in the excerpt below. All items in parentheses represent notes or memos made in transcriptions. Material in brackets represent a synopsis of statements made by the researcher during the session.

<u>Log Excerpt : Teacher GB (Pre-Activity Interview 9/19/88)</u>

> I worry about using the computer. I don't want to use it before I am ready. I am frustrated. Like the other day I tried using the computer, you know those disks he had given us - (these were the software programs from the workshop) I

didn't get too far with any of them. It's really frustrating because you think it's really simple and yet there are things that don't go right. When you are teaching children and things don't go right...You lose kids that way. They're waiting, they're waiting for you and you don't know what to do and that's where you lose your class sometimes. If it doesn't work right, what do you do next? [I suggested a dress rehearsal, a dry run before she presented the lesson to the class].

I did a dry run the first day of school. I never used a computer with a printer before so I had to go to my computer aide and she had to help me. You can see the printer, It's right there, (she pointed to a printer in the corner of the room) and I will have a computer right in the room. And the computer room is right next door and if there's not a scheduled class, I could take them there. I'm very lucky, in that sense.

So, the first day I took a dry run. I was afraid that I might do something wrong. It wasn't coming out right. It (the computer) said 'no data for this'. I was wondering did I erase something? I didn't know why they didn't have it (the data). I thought when we practiced at Jefferson school, that we had it. And the computer person came in and said 'did you take out the disk when the red light was on?' I said, 'Ohh, I might have done that...'

I want to be very, very sure that I don't erase any programs on the computer. I'm not sure what's on there. For example, today they (her students) are going to measure themselves and we are going to use it for the first lesson on the computer- in the graphing. I wasn't sure when I was trying to put this in the computer - just what goes on the x-axis and what goes on the y-axis? And it [the computer] says, 'give it a name' and I did that. And it says, 'Now choose a field' or something, I don't know exactly what the question was. But I had difficulty doing that because when I put the thing in and it says 'Not enough information' it might have been something very simple that I had to do, but I didn't know what.

The log served not only to record observations and events but as a tool for analysis as well. As Bogdan and Biklen (1982) suggest, such a log helps the researcher keep track of the development of the research, to visualize how the research plan has been affected by the data collected, and to remain selfconscious of how he or she has been influenced by the data. As the data were being gathered, the researcher read and reread the log, writing memos, coding, and looking for patterns and formulating hunches. This kind of work on the log provided the basis of the formulation of analytic questions. The researcher planned subsequent data collection in light of what was found in previous information. This cycle of data collection and data analysis continued during the fieldwork period until the study was focused and narrowed, and a general description and explanation of that narrowed phenomenon was established. Various techniques were used in the analysis, such as triangulation, saturation, alternative hypothesis testing, the search for similarities (common themes), dissimilarities, resolution of inconsistencies, the isolation of key events, and memoing.

Using Miles and Huberman (1984) as a guide, analysis after data collection consisted of data reduction, which involved making summaries, identifying clusters, making partitions and writing memos. This was done by researcher interpretation of the data. A second major analysis activity involved making data displays. According to Miles and Huberman, a display is an organized assembly of information that leads to understanding what is happening and permits conclusion drawing. Display formats used were in forms such as a summarizing table, a matrix, or a diagram expressing linkages and interactive structures (models). Theme clusters and interactive structures were identified and grounded theories were verified with periodic reentry into the field for needed information.

The extent of implementation was based on two measures, one quantitative and one qualitative: the percentage of lessons completed, ar. the degree of match between teacher behaviors and behaviors expected by the developers. (The teacher behaviors checked were those which indicated facility with the calculator or computer, knowledge of the developer's underlying principles and their presentation, presentation of the desired mathematical topics and concepts, and effective classroom management while using the technology-based materials). A graph of the relation of the two indices was constructed as seen in Figure 1.

INSERT FIGURE 1 ABOUT HERE

Examining the dispersion of these measures for the calculator innovation, three distinct groups emerged: a large group for which a linear relationship exists between quantitative and qualitative efforts, and two small groups, one exhibiting high quality and low quantity and one displaying high quantity and low quality[1]. Linearity of the large group of points was corroborated by a correlation of 0.73 (N=11). The distribution of implementation points generated a number of analytic

[1] The large group consists of points JS, JM, DR, AS, MM, GB, BC,CB,SM AND AA. The small groups consist of points RB, BR and points CK, CY, WW, and ES, respectively.

questions, some of which led to reentry into the field to gather data that would answer these focused questions. Analytic questions included: Why did teachers (WW, ES, and CY), who show the potential for high quality implementation, complete so few lessons? Why did teachers RB and BR complete so many lessons but not perform according to the expectations of the innovation? What factors contributed to the result that 11 out of 16 teachers completed less than 75% of the lessons? Could anything be done to help the 8 teachers in the low quality group to perform more effectively?

A quantitative index of calculator implementation was formulated: $I = QN$, where $\underline{I}$ is the overall index of implementation, $\underline{N}$ is the fraction of lessons completed and $\underline{Q}$ is a qualitative weighting factor, describing the effectiveness in fulfilling the objectives of those lessons. This index provided an extent-of-calculator-implementation scale which was used in the analysis to determine relationships between potential factors and degree of calculator implementation. It was found that the overall extent of implementation of the calculator was moderately low; only four of the sixteen teachers implemented the innovation on a maximal level.

The analytic process alternated between qualitative and quantitative methods, most often it began with qualitative or interpretative analysis and ended with predominately quantitative analysis. For example, to determine factors that were related to the extent of calculator implementation, a data display matrix was used as suggested by Miles & Huberman (1984). The factors considered were teacher age, sex, teaching experience, personal commitment to the project, skill/knowledge, pre-activity attitudes, training & support, collegial interaction, the SMMTS materials, teacher learning beliefs, perceived rewards, availability of hardware, complexity of the hardware, student ability levels, scheduling, site, other school commitments or priorities, and time. Some of the factors were suggested by the teachers themselves as explanations for extent of implementation, whereas others emerged from reading the incoming data. The researcher listed vertically the teachers in order of degree of implementation and horizontally the number of factors which appeared to be correlated with the extent of implementation. A sample of this data matrix is presented in Figure 2.

INSERT FIGURE 2 ABOUT HERE

Three conditions emerged as coexisting with maximal calculator implementation: high teacher commitment, positive pre-activity attitudes, and a display of skill and knowledge. Continuing the analysis with a more mathematical perspective, a Venn diagram was constructed showing how these qualities were distributed among the teachers along with the implementation scale for reference (see Figure 3). Displayed in such a manner the data revealed that all three attributes were necessary for high implementation and that no one attribute dominated, in general, as a teacher lies further from the intersection, that teacher is found further down the implementation scale. To corroborate the first observation, conditional probabilities were calculated. In this study the probability of successful calculator implementation given high skill and knowledge (P=.50) was equal to the probability of success given high personal commitment and that the probability of success was slightly lower given positive attitude (P=.44). Thus, it appears that none of these attributes is stronger than the others.

INSERT FIGURE 3 ABOUT HERE

### Barriers to Implementation: How They were Determined

Information from classroom observations by the researcher as well as other members of the SMMTS staff, from discussions with the participant teachers, from written lesson evaluations, and from overall contact with project personnel all provided a basis for identifying barriers to the implementation. Teachers were asked why they did not complete the activities and what factors were most helpful and most hindering. The principals and the Mathematics Coordinator were also asked these questions. From their responses and the findings above, barriers to the implementation were identified. The analysis was predominately qualitative, relying on observational and interview data as recorded in the log.

For example, one barrier was identified as teacher beliefs in conflict with the goals of the SMMTS materials. This includes teacher beliefs that the materials were too difficult for a particular group of students, that the topics were not appropriate for the grade level, or that the use of calculators will reduce mathematics learning. The following excerpt is an illustration of the data used to support this finding.

> I assume it's bad to rely on the calculators too much. What if I assign something and they never think about it in their own minds? When do they learn how to multiply properly? (Teacher AS, PAI 11:46-52[2])
>
> I'm not sure I do understand why negative numbers are important in second grade. I'm not sure that I understand that at all. There's so much else that they have to absorb. (Teacher DR, EI 67:30-34)

In the Exit Interview nine out of fifteen responding teachers said that they thought that the

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[2] The following codes are used to refer to the data.
EI = Exit Interview
T = Follow-up telephone calls
OBS = Classroom observations
WE = Workshop questionnaires
PAI = Pre-activity interview
Q = End of the year Questionnaire
LOG = General log information
P/A = Principal/Administrator interviews
SEQ = Self Evaluation Questionnaire
These codes are followed by the page and lines quoted, or by the date of the event. Examples: EI 54:12-22 or EI 6/6. (Russek, 1991, raw data from the study).

SMMTS materials were inappropriate for their students. These teachers felt that the lessons were too difficult for their students, that the topics were not appropriate for the grade level or that the calculator would discourage the children from learning number facts and algorithms. Teacher JS used the fourth grade materials for her fifth grade students saying, "some of it I thought was inappropriate for the grade level. The level of difficulty I didn't feel was realistic." Teacher MM stopped presenting the lessons to his fourth grade in February, saying

> I've gotten up to Lesson 7, and no, I don't think I'm going to go on. I just think they're not appropriate for my kids. I think it's frustrating rather than illuminating so I have sort of given up on that score... I thought the kids just didn't get what we were trying to teach, you know, like you could add and subtract exponents to do calculations and I think the estimating of products was too hard. It was above them. They weren't that interested in it. I think that might be a little bit mature for 4th graders, at least <u>these</u> 4th graders, to carry out (EI 37).

In a number of instances collected qualitative information triggered statistical inquiry, as illustrated by the following excerpt from the analysis:

> I lacked a fellow teacher in my building to share problems with. Being able to call Ken or Rich for expert help is one thing, but having fellow teachers as much in the dark as you are and both of you making discoveries and sharing support, is another. (Teacher CB, EI 6/89)

Because of the frequency of such statements, the correlation between the quantity of lessons completed and working with a fellow teacher was computed. The correlation was found to be 0.56 (n=16), indicating a moderate correlation.

Barriers to the calculator implementation fell into three main categories, those associated with teacher characteristics, those associated with the materials or the innovation, and those associated with the organizational arrangements. All of these barriers were present to some degree for all the teachers. Some teachers were able to overcome them and some were not. The barriers were seen as working in concert, presenting the teachers with multiple and compounded difficulties. Table 2 presents the number of teachers who reported that a particular condition hindered or terminated their efforts to implement the innovation, and the number of teachers who were assessed by the researcher as having inadequate skill and knowledge to perform effectively. The table reveals that those teachers who were assessed low in skill and knowledge reported more obstacles to implementation. The average number of barriers (excluding Skill/Knowledge) reported by teachers with low Skill/Knowledge = 5.3. The average number of barriers reported by teachers with high Skill/Knowledge = 2.5. This finding corroborates the expectation that those teachers who had less skill and knowledge would perceive more difficulties putting the lessons into place.

INSERT TABLE 2 ABOUT HERE

For the Computer the findings reveal three major barriers to implementation. These barriers became apparent early and continued to affect implementation throughout the year. They were:

> The requirement for computer expertise. This includes knowledge about the micro-computer operating system (DOS), ability to "set-up" the equipment, run an overhead projector, a printer etc., knowledge of the software packages--their contents and how to use them.
>
> Difficulties with the equipment. This includes the time and ability necessary to gather the equipment and assemble the hardware, such as looking for plugs, y-connectors, carts, printers, and overhead projectors. This also includes security concerns.
>
> Difficulties with the whole-class demonstration format. The format was accompanied by a host of class-management problems.

Except for positive attitude, the attributes which characterized teachers who maximally implemented the computer innovation were the same as the attributes associated with maximal implementation of the calculator innovation. These attributes are: high teacher commitment and a display of skill and knowledge.

In the case of the computer, all participating teachers indicated positive initial attitudes with respect to its educational authenticity and its desirability in the curriculum. This finding is consistent with conclusions of Suydam (1984) who, in a review of research, concluded that microcomputers are generally accepted as a valid educational tool, whereas an emotional fear of calculator use is evidenced. However, in contrast to the calculators, most teachers expressed a high level of anxiety in anticipation of use of the computer. This anxiety continued throughout the year. That is, two components of attitude were identified, one component had to do with the belief of the educational validity of the innovation and the other had to do with personal feelings of anxiety in handling the computer. The quantitative measures used did not identify these two components.

It was concluded that the implementation of these two technologies in this school district faced very serious barriers that were not easily overcome. Teachers with above average determination and innate skills were able to implement effectively, but the others were not able to do so. For the typical teacher, these barriers were formidable.

In conclusion, ethnographic techniques offer another research perspective which could be extremely useful to mathematics educators. According to Eisenhart, (1988) numerous mathematics education researchers, particularly those interested in what teachers or students are thinking and actually doing in classrooms, are posing questions for which ethnographic research is appropriate. However "relatively few researchers have actually undertaken ethnographic research, that is, the holistic depiction of uncontrived group interaction over a period of time,

faithfully representing participant views and meanings."
Because the research questions in this study were the nature of, "What is going on here?", the use of ethnographic techniques provided an appropriate framework for data collection methods and data analysis. However, quantitative instruments, properly validated by the ethnographic techniques in the setting of the present study, extended the scope of the study well beyond that which could be realistically accomplished by traditional ethnographic techniques alone. Moreover, the quantitative aspect of the present study permitted numerical indices to be formulated, thus providing a depth of understanding of the phenomenon being studied that would not have been accessible by qualitative statements alone.

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Table 1

Triangulation
Quantitative Degree of Implementation

| Teacher | Teacher verbal reports | Classroom observations | LEF |
|---|---|---|---|
| | DATA SOURCES | | |
| WW | LOW | LOW | LOW |
| ES | LOW | LOW | LOW |
| EM | MODERATE | MODERATE | LOW |
| DR | MODERATE | MODERATE | MODERATE |
| RB | HIGH | MODERATE | LOW |
| BR | HIGH | HIGH | HIGH |
| AA | HIGH | HIGH | LOW |
| CB | HIGH | MODERATE | HIGH |
| MM | HIGH | HIGH | MODERATE |
| AS | MODERATE | LOW | LOW |
| CY | LOW | LOW | LOW |
| SM | HIGH | HIGH | HIGH |
| GB | MODERATE | MODERATE | LOW |
| BC | HIGH | LOW[a] | LOW |
| JS | MODERATE | MODERATE | LOW |
| CK | LOW | LOW | LOW |

[a] The last date observed was 2/7. Therefore, it is very possible that she completed all the lessons after this date. Also the teacher's report was corroborated by samples of completed student workbooks.

Table 2

Barriers to the Implementation

(n=15)[a]

| Barriers | JS | CK | DR | JM | CY | RB | ES | WW | MM | BR | GB | BC | CB | SM | AA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Teachers[b] | | | | | | | | | | | | | | |
| Lack of Skill/knowledge[c] | x | x | x | x | | x | | | x | x | | | | | |
| Teacher conflict with SMMTS goals | x | x | x | x | | x | x | | x | | x | | | x | |
| Materials/lesson difficulties: | | | | | | | | | | | | | | | |
| timing | x | x | x | x | | | x | x | x | | x | x | | x | |
| presentation | x | x | x | x | | x | | | | | | | | | |
| length of lessons/background | x | x | x | x | | x | | x | x | x | x | | | x | |
| Operational difficulties | x | x | x | x | x | x | | | x | x | | x | | | |
| Lack of time - conflict with other school commitments | x | | | x | x | x | x | x | | x | x | | | | x |
| Lack of support/interaction | x | | x | x | | | | | | | | | x | x | x |

[a] Teacher AS has been omitted because this information was not obtained for her.

[b] The teachers are listed in order of degree of implementation, from least to most.

[c] Skill/knowledge was assessed by the researcher. All other barriers were identified by the teachers.

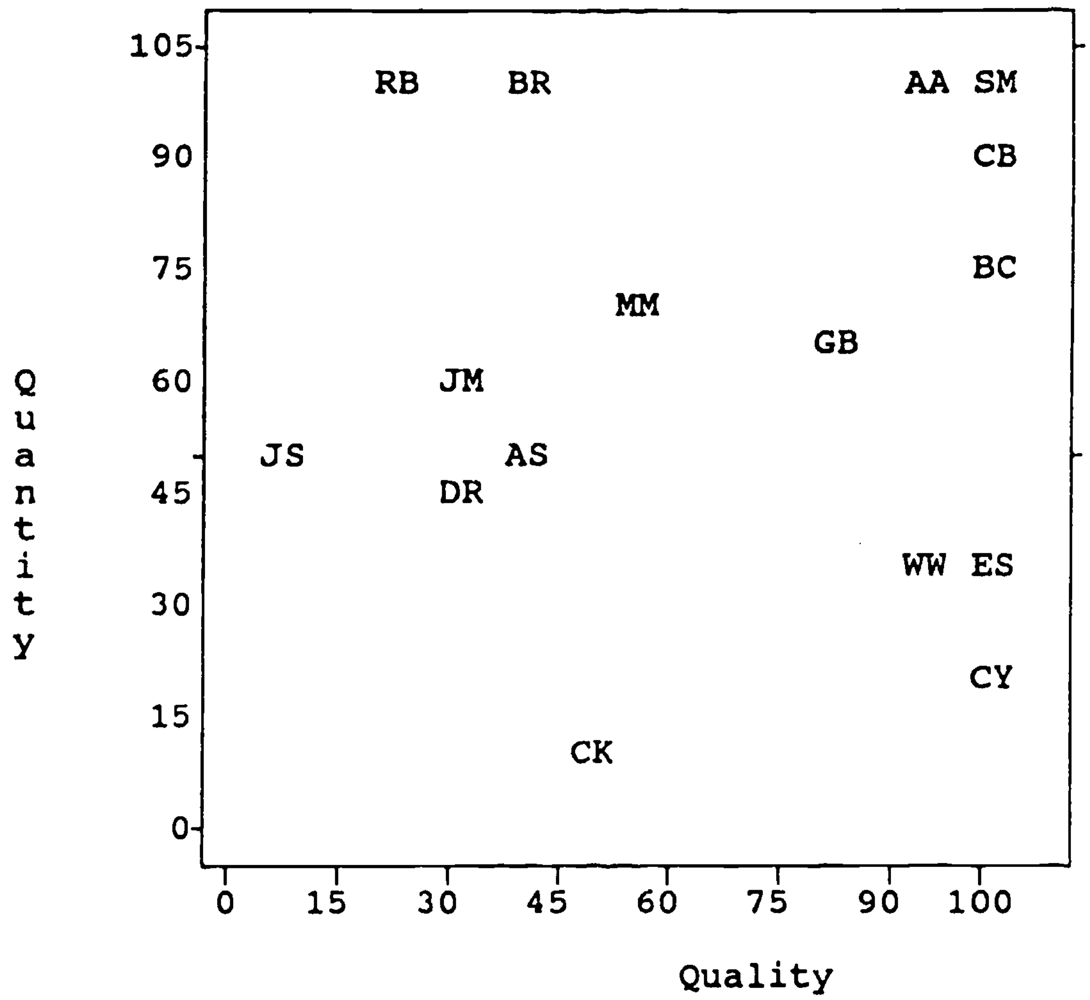



Figure 1 Extent of Calculator Implementation: Quantity versus Quality

(n=16)

| Teachers (In order of extent of implementation) | Expressions of Personal Commitment | Volunteer Status /Pre-activity Attitude | Skill/knowledge |
|---|---|---|---|
| AA | High<br>"You just do it yourself" | High<br>Requested/"I was excited and still am" | High<br>Observations; 11/4, 1/31, 5/24 MC, OO[a] |
| SM | High<br>"I said I would do it and I did. I made a commitment to something and I had some doubts along the way, and I stuck through it." | High<br>Requested/"Look forward to the challenge!" | High<br>Observations; 10/25, 12/6, 5/24 MC,OO |
| CB | High<br>"Teacher motivation" | High<br>Requested | High<br>"I felt comfortable with the calculator activities and share my knowledge with the children." (also Obs 2/7); MC |
| BC | High<br>"My commitment" | High<br>Requested | High<br>Observation 2/7; MC |
| GB | Mod<br>"I think I over-committed myself. I have so many other things to do." | High<br>Requested/"I'm ready to jump in, I'm ready!" | High/Mod<br>"I'm still not comfortable with memory, because I'm not always sure what I put in memory and what I come out with is always the right thing". MC |
| BR | High<br>"My commitment" | High<br>"I think it's exciting." | Low<br>Observations; 10/10, 2/8, 5/24; MC, OO |
| MM | High<br>"I think it's the right thing to do" | High<br>"positive feelings" | Low<br>"I need a lot of time to master the lesson so I know what I'm doing" P, MC, OO |
| ES | Low<br>"What do they have then in that little pack we got over the summer? -which I have to locate?" [She hadn't looked at the materials yet, 10/13] | Low<br>"I didn't volunteer,...the principal selected me"/ "wait-and-see" | High<br>Observations; 12/12. 4/12; OO |
| WW | "It wasn't that I said, 'I'll either do the calculator or do that'. It was more a matter of, 'I need to do this other thing before the calculator'." | Low<br>"I didn't volunteer...it was suggested to me"/ "I will wait and see if it fits into the program." | Low High<br>Observations; 12/12. 4/7; MC, OO |

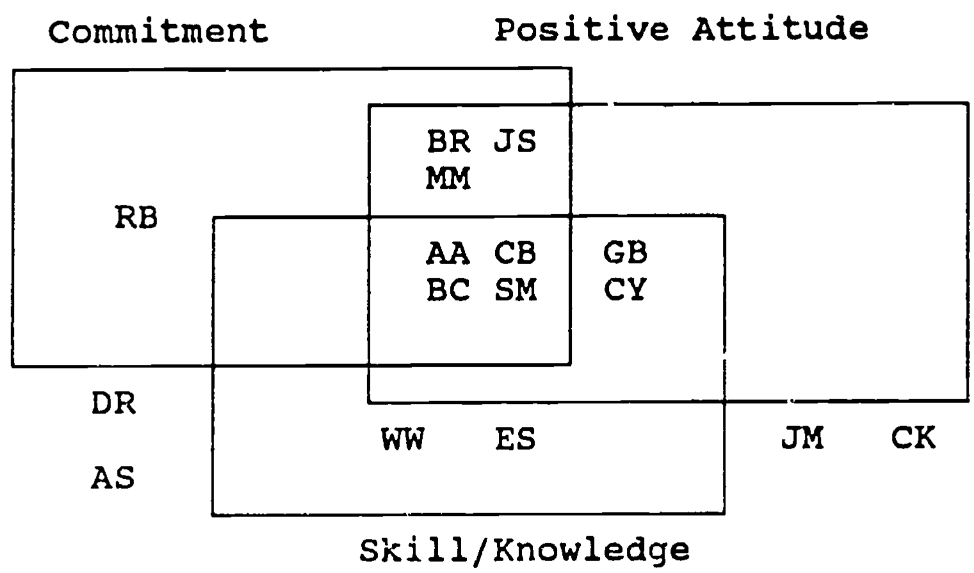
Figure 2 Factors Associated with Extent of Calculator Implementation

| Teachers (In order extent of implementation) | Expressions of Personal Commitment | Volunteer Status /Pre-activity Attitude | Skill/knowledge |
|---|---|---|---|
| RB | "We did it on our own, on our own time and in the classroom and that was it." | High<br>"I was asked if I would like to and I said, 'Why not?'"/ I feel if there is a need to put technology into the math curriculum I'd like to see how it's done. /"healthy skepticism" | Low Low<br>see EI pp. 6,9; Observation 5/18 MC, OO |
| AS | Low<br>"I haven't really examined the program yet." (9/23/88). | Low<br>"We did have the option of saying 'no', but...we were sort of elected."/ "Right now I assume it's bad to rely on the calculators too much...When do they learn to multiply properly?" | Low<br>Observations; 11/4. 1/31 P, MC |
| CY | Low<br>"I just couldn't find the time to do the activity properly." | High<br>Requested/"It should be easy to include in my situation, because I only teach math and science, and I can devote the time that I need." | High<br>Observation 2/7); MC |
| JM | "When we got to March I said, 'I can't do another calculator lesson. We'll work on studying for the Iowas. - And I was relieved because we could study for the Iowas." [instead of using the calculators]. | Low<br>"I didn't volunteer. The other teacher moved to the fourth grade, and that left me."/ "I don't like to play around with the calculator, I was never a 'number' person. I'm willing to do it, I like to try new things." | Low/mod Low<br>I found myself having to read it [the Teacher's Guide] over. I would to home and try to see if I could do [the lesson. Sometimes I wasn't clear on a couple. It wasn't always understandable -to me." (EI 84); MC |
| DR | Low<br>"..this was not my first choice"..."Okay, I'm going to try it. But I've been resistant to this sort of thing for the lower grades." | Low | Low<br>"What's wrong with me? Why can't I figure this out?" "I'm not comfortable with it. Really before a lesson I've got to really 'bone up' and work it and think about what I'm going to say in terms of the |

[a]Comments by other observers. MC = Mathematics Coordinator, OO = Other Observers, P = Principal

Figure 2 (con't) Factors Associated with Extent of Calculator Implementation

I. Intersections of the Three Factors




II. Calculator Implementation Scale

low — high

JS CK DR JM CY AS RB ES WW MM BR GB BC CB SM AA

Figure 3 Teacher Characteristics and Degree of Implementation