

# **Reluctant Reformers' Instructional Practice and Conceptions of Teaching Calculus When Using Supercalculators**

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A major topic of interest concerning the future of mathematics education in recent years has been the use of calculators and computers as tools in the teaching and learning process. The movement for widespread integration of technology in the college mathematics classroom can be separated into three overlapping phases. In the first phase, identified as the "recognition" phase, individuals and organizations became aware of the need to improve mathematics instruction and recognized the use of technology as a means of facilitating learning. The second phase was initiated when teachers and researchers began to "experiment" with ways to utilize the technology in teaching in order to improve student learning and also to explore how the innovation may affect the mathematics curriculum. It is during the third or final phase of "acceptance", that the new methods of teaching through integration of the technology will become the preferred way of teaching by the mathematics community as a group. Substantial effort has been made in the second phase as can be attested by the many workshops, minicourses, sessions, and papers that will be presented at this conference. However, there is still much that must be done before the third phase can become a reality.

When new technology is to be implemented into teaching a particular subject, it is important to examine how the teacher views the innovation, its value as a teaching tool, and how it is adapted into instruction (Jost, 1992; Thompson, 1992). Lewis (1988) found the teacher's perception of the importance of the innovation was the determining factor in the effectiveness of the implementation of the innovation. In the past, teachers who have experimented in teaching with technology have been motivated to do so based upon positive feelings, beliefs, and experiences concerning its use. Implementation of computer software and Scientific-Programmable-Graphing (SPG) calculators has now reached the point where key faculty members are persuading mathematics departments to adopt curricula that integrates technology into instruction and learning. However, the adoption of technology-oriented curricula and the acquisition of technology will not be enough to ensure its successful integration into teaching. Possible adjustments and changes must be viewed in terms of the teacher who ultimately determines how the technology will be utilized in the classroom.

How will teachers, who are not the catalysts for curriculum reform or the advocates for the use of technology in college mathematics courses, respond when requested to teach with technology? To address this question, a study was conducted which investigated classroom instructional practices and teachers' professed conceptions about teaching when asked to integrate the SPG calculators into the college calculus curriculum.

## **Methodology**

### Context of the Study

A Mathematics Department at a state university located in the western part of the U.S. had recently chosen to experiment with the use of SPG calculators in the first year calculus sequence and had adopted a calculus textbook that incorporated SPG calculators within the presentation of the topics. The university was not affiliated with a funded or sponsored reform project and the teachers participating in the study were not the catalysts within the department seeking calculus reform. Five subjects from a pool of 10 instructors assigned to teach first quarter calculus Fall 1993 were selected to participate in the study. Each of the teachers in the study had expressed a willingness to teach the calculus course with the technology, but none of them had used SPG calculators previously in teaching calculus. Four of the five participants were unfamiliar with SPG calculators prior to the study and one had use another type of SPG calculator in teaching statistics and algebra courses. The subjects for the study included one full professor (Arthur), one associate professor (Brooke), two lecturers/instructors (Clark and Edward), and one graduate student/instructor (Dean). Pseudonyms were provided for each of the teachers to preserve anonymity.

### Procedures

Because there was a desire to allow important variables to emerge naturally from the data, qualitative methods were employed. The constant comparative method suggested by Bogdan and Biklen (1992) was used so that preliminary analysis could occur during data collection to help direct further data collection and analysis. Primary data for the study came from several sources including: (a) an initial interview with each teacher (to establish baseline conceptions regarding teaching and learning calculus and the use of SPG calculators), (b) a second interview with each teacher after they participated in the calculator training workshop prior to the beginning of the quarter (to expand on the baseline conceptions of the teachers and to determine if the training had influenced the teachers' conceptions of teaching the "calculator" calculus course), (c) weekly observations of the participants teaching their calculus course with extensive field notes taken by the researcher (to document classroom practice), and (d) informal discussions subsequent to an observation (to review the lesson). After the conclusion of the quarter, an extensive final interview was held with each participant. All interviews and observations of lessons were audiotaped and transcribed. Supplemental data were collected from the textbook and from teacher made documents (syllabus, lesson plans, exams, quizzes and handouts given to the students during class).

Analysis of the data took place in three stages. First, the initial interviews (pre-training and post-training) were analyzed to establish each teachers' baseline conceptions. The second stage of analysis began as the weekly observations were conducted through which preliminary teaching patterns appeared and individual teacher categories were established. During this stage of analysis, preliminary teacher profiles were developed. The final stage of analysis occurred after the completion of the final interview when all the data were re-evaluated and the teachers' characteristics were refined to form the detailed teachers' profiles.

Although several characteristics emerged from the data regarding the participants' conceptions of teaching and learning calculus in connection with their general instructional practice, the focus of this paper is to discuss the teachers' conceptions regarding the use of the SPG calculators, their actual classroom instructional practice with SPG calculators, and some of the factors that

influenced the teachers' use of the SPG calculators in the classroom. (For more details of the study, see Barton, 1995.)

## Summary of Results

### Initial Conceptions about Using the SPG Calculators

The four teachers with no prior experience with SPG calculators expressed reservations concerning the potential effectiveness of the calculators in assisting them in teaching calculus. Illustrative comments made by the teachers who were dubbed "reluctant reformers" included:

Arthur: I'm not convinced it is the right thing to do, but it appears to be the wave of the future. And if so, I'm going to investigate its use. I don't know whether it has a beneficial, or negative, or neutral affect, but it will have some effect.

Brooke: You [will] have a much harder time to motivate and to make them do the things that you want them to do because they say, "Oh, the calculator does it for me, why do I have to learn to do this by hand?" So I think, you [will] have a much harder time trying to motivate the students to do the problems.

Clark: I am not jumping up and down just full of excitement about it even though I am a computer nut I guess.

Edward: If it gets to the point that they are saying this thing is worthless, I can't get anything out of it, then we will drop it, because I am well familiar with the frustrations that come with computers.

The one teacher having prior experience in using a SPG calculator in statistics and algebra courses expressed optimism about the use of the new technology in the calculus course and was looking forward to utilizing it as a tool to assist him in teaching calculus. Dean stated, "I think it is great! It is about time! I have no problems with that. I think it is really a nice tool."

The three most skeptical about using the SPG calculators (Edward, Arthur, and Brooke) indicated initial concern that the calculator might dominate the course. If that became the case they believed it would be better to discontinue its use, since their primary objective was to teach the calculus not the calculator.

All of the teachers in the study did not initially believe incorporation of the SPG calculators would make a significant difference in their teaching approach. Additionally, when initially interviewed, none of the teachers had well-formulated conceptions about how the calculator could be used to assist them in teaching the calculus. All four teachers having no prior experience with any type of SPG calculator suggested it would be used for graphing functions, but were unable to provide explicit examples. Dean who had some experience with SPG calculators also did not have well established conceptions of how the calculator would be used in teaching the calculus course. The general examples he mentioned were about graphing within an algebra context.

Three of the five teachers (Arthur, Brooke, and Edward) believed the SPG calculator was being implemented because it was available, it was the fashion to do so, and was a means of maintaining respect and credibility in the midst of the technology age. Only one teacher in the study (Clark) did not mention academic respectability as a reason for implementing the technology. Rather, he gave reasons more in line with those suggested by the reform movement proponents (to help illustrate ideas geometrically instead of algebraically, to allow for more investigation of ideas and concepts, and to be able to look at more examples.)

As a matter of note, analysis of the pre- and post-training interviews indicated the hour and a half calculator training workshop did not have a significant influence on the teachers' conceptions of teaching calculus utilizing the SPG calculators. After the workshop, the teachers still were unable to describe explicit ways they intended to use the calculator in their presentation of the calculus topics.

### Use of the SPG Calculator in the Classroom

All the teachers in the study experienced "first time" difficulties using the calculator in class which affected the type and amount of use it received. Since the textbook adopted by the department did not rely heavily on the use of SPG calculators in working the problems or in the development of the concepts, the teachers had considerable flexibility in how often and the manner in which they utilized the calculator. Consequently, there were notable differences among the teachers in the amount of use the calculator received during class. However, the calculator was primarily used in each of the classrooms to visually illustrate graphs of functions. The two teachers, who utilized the SPG calculator most frequently in their lesson presentations, viewed the calculator both as an important instructional tool for them in the classroom and as a learning tool for the students.

Although the teachers' usual classroom practice did not look substantially different from traditional lecture style college calculus classes, some of the teachers utilized graphical intuitive strategies to illustrate concepts or theorems instead of stating rigorous definitions or proofs. Since these teachers had not been observed teaching the calculus course prior to the study it is not known if the intuitive approach may be attributed to either the implementation of the technology or the graphing approach suggested by the textbook. However, when asked about their teaching approach, three of the five teachers mentioned they believed they had taught in a more conceptual or intuitive manner when presenting the calculus topics and had de-emphasized the rigorous proofs of theorems than when they had previously taught the calculus course.

### Professed Conceptions at the Conclusion of the Study

All four teachers who initially indicated some skepticism about incorporating the calculator in the calculus course professed improved conceptions about using the calculator by the end of the study. Additionally, all of the teachers in the study stated the SPG calculators should continue to be incorporated into the calculus course.

For three of the teachers there was not a dramatic change in their professed conceptions concerning the use of technology in the calculus course. Interesting, the teacher who initially voiced the strongest skepticism, demonstrated the greatest change in attitude and conceptions about using the calculator in the calculus course. After a single experience in teaching first quarter calculus using the SPG calculators in his class, Edward stated, "I would never want to teach that class without it, having [now] done it. And I was the biggest skeptic. I was leading the charge against it, [saying] 'Let's not do it.' last spring." Edward's willingness to risk class time in utilizing the calculator and also having students demonstrate features of the calculator during class may have been contributing factors in his change in attitude.

For most of the teachers in the study, a change in conceptions concerning the technology was not instantaneous. Rather, the change came in a gradual manner as the teachers had more experience using the calculator in class. It may be conjectured that increased effective use of the technology to assist in teaching the concepts of calculus may also be a gradual process.

### Factors Influencing the Use of the SPG Calculators

Some of the factors **inhibiting** implementation of the technology into instruction determined from the study were:

- The teachers' inexperience in operating the SPG calculator
- Limited time both within the classroom and in preparation for class
- The teacher's strong conceptions toward a theoretical approach emphasizing precise wording of definitions and proofs of theorems
- Teaching primarily for skills acquisition
- The teacher's lack of knowledge of the subject
- Lack of interest from students
- Assembling the viewscreen each class period
- The physical arrangement of the teaching environment (classroom)

Some factors **promoting** the use of the technology during instruction included:

- The teacher's familiarity with the features of the calculator
- Using an intuitive or conceptual approach in discussing the concepts
- Extended class periods
- A willingness on the part of the teacher to risk the limited class time in demonstrating concepts with the calculator
- A strong desire on the part of the teacher for the students to learn how to use the technology
- The calculator viewed by the teacher both as an instructional tool and as a learning tool

### **Suggestions for Assisting Reluctant Reformers in Implementing Technology into the Mathematics Classroom.**

The conclusions drawn from this study are not generalizable to the total population of college calculus instructors incorporating technology into their teaching. However, it is hoped the

conclusions formed across the five case studies provide insight and a better understanding of the situation being faced by "reluctant reformer" teachers. In connection with the results of the study, several suggestions to assist mathematics departments in implementing new curricula involving technology emerged:

- Extensive training should be given the faculty members prior to teaching the course to assist them in becoming familiar with the capabilities of the calculator before preparing their lessons.
- On-going hands-on workshops/seminars throughout the course are needed to teach the use of the calculator for specific topics, to provide examples of strategies/methods for effectively using the technology in the classroom, to allow the teachers the chance to share ideas they have tried in the classroom, and to discuss possible difficulties.
- There may be the need to bring in a "technology expert" for a while to assist in the training of the faculty. The department must establish at least one inhouse "expert" who can competently take over when the outside "expert" leaves.
- More readily available "legitimate" resource materials are needed for the reluctant reformer teachers. (Legitimate materials are what the teachers believe to be worthwhile, useful, realistic, or real world.)
- Physically arranging the classroom for easy use of both the display unit (viewscreen) and chalkboard (whiteboard) is critical for the reluctant reformer teachers who are using the technology. Poor physical classroom facilities are serious obstacles for implementation.
- Scheduling the calculus classes in the same rooms for consecutive hours will allow the teacher's display unit (viewscreen) to remain set up for consecutive classes. Even though the display is easy to set up, the reluctant reformer calculus teacher may find it too bothersome to set up every class period. Consequently the display unit may not be utilized to its full potential if it must be assembled by each teacher for each class period.

Since the teacher is the primary mediator between the subject matter and the student, it is essential to continue to learn more about the "reluctant reformer" actions in regards to the use of the technology in the mathematics classroom. This study has provided an initial step in understanding college teachers' conceptions and first experiences of implementing technology in the teaching of calculus. As we enter the third phase for integration of technology into the mathematics curriculum, it will be necessary to enlist the services of college mathematics faculty who are not familiar with the technology or with the curriculum reform ideals. They will need assistance in learning beneficial uses of the technology and effectively utilizing the technology to maximize student understanding of the mathematical concepts. This is the challenge that now lies before us.

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