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EFFECTIVE INSTRUCTION IN COLLEGE MATHEMATICS

Lynda M. Zamora-Wilson
B.S., California State University, Chico, 1991

Thesis

Submitted in partial satisfaction of the
requirements for the degree of

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at

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EFFECTIVE INSTRUCTION IN COLLEGE MATHEMATICS

A Thesis

by

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Department of Teacher Education

Abstract

of

EFFECTIVE INSTRUCTION IN COLLEGE MATHEMATICS

by

Lynda M. Zamora-Wilson

Statement of the Problem

Recent studies show a high attrition rate in college mathematics courses. Analysis of student ratings of their mathematics classes indicates that poor instruction and "unapproachability" of their instructors were the principle reasons for student drop-out. Of the students being filtered out of college mathematics, women and most minorities were found to be the majority; therefore those groups are highly underrepresented in this field. With the ever-increasing size and diversity of the population of the nation's colleges and technical fields, it is clear that mathematics instruction needs to be studied in order to discover successful strategies that meet the needs of all students.

Sources of Data

Information was obtained through research of related literature and personal communications with mathematics instructors.

Conclusions Reached

While it is common knowledge to mathematics instructors that college mathematics is usually taught directly via lectures, results from studies suggest this method to be highly inefficient for students' conceptualization. Experimentation with several "student active" strategies, however, have been shown to develop students' proficiency in mathematics. With the implementation of such successful strategies, the needs of a greater range of students can be met, thereby promoting motivation and growth in the mathematical fields.

Edward Arnsdorf, Committee Chair
Edward Arnsdorf

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Lynda M. Zamora-Wilson

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Chapter 1

INTRODUCTON

The purpose of this research was to identify instructional strategies in college mathematics which are successful in promoting student learning. It was the author's purpose to focus beyond the traditional lecture method to discover alternate strategies that have been shown to be effective for the diverse spectrum of students.

Statement of the Problem

The population of the nation's colleges is changing at an ever-increasing rate. Diversity has flourished to the point where the formerly underrepresented sector (women and most minorities) is near majority. Yet, while there is an increase in diversity among the collegiate populace as a whole, there remains an ever-decreasing number of mathematics majors. A study in 1990 by Tobias showed that of the students majoring in science, mathematics, or engineering, over 40 percent left the science field. In fact, the drop in the number of students majoring in the science field was greater than that of any other field. In a time when technology is rapidly increasing, a loss in expertise in this area could become critical to the economic well being of our country. Further analysis shows that many of the students being filtered out of the mathematics field are women and most minorities (National Council of

Teachers of Mathematics, 1992); therefore these groups are highly underrepresented in this discipline.

Students themselves were concerned over the quality of the mathematics instruction they had received. Research indicates that their responses can help identify reasons for attrition in the mathematics major and also help target the needs of students which are not currently being met. In Tobias' 1990 research, student ratings in science and mathematics courses were collected. In the analysis of the ratings, frequent comments of poor instruction and "unapproachability" of the instructors were noted. In 1993, Loftin performed a factor analysis which revealed specific concepts which concerned students who were majoring in science and mathematics. Of the seven identified concepts, the first three were cited as "instructor presentation skills," "student perception of personal progress," and "student-teacher interactions" (Loftin, 1993).

With diversified student population and high attrition rate in mathematics majors, universities are risking a high failure rate in mathematics. With this dismal information it is clear that there needs to be a change, but a change in what?...In the instruction?...In the curriculum?

Methodology

Due to the lack of available material on college mathematics instruction, the focus of this study was broadened to encompass research in instructional strategies of college and secondary mathematics. Presented was the historical and descriptive research compiled from available studies and personal interviews. Within the

strategies, two main themes of successful instruction became apparent: methodologies and behaviors. Focusing on these themes, information was obtained, developed and presented pertinent to college teaching.

Delimitation

This study was written for use by mathematics professors only to identify the techniques which lead to efficient student learning.

Definition of Terms

Behaviors: The internal characteristics or traits that constitute personality.

Complex mathematics: Mathematics courses beyond calculus levels.

Efficacy: Power or capacity to produce a desired effect; effectiveness in learning.

Establishing community: Participating fellowship interacting with one another in the sharing of ideas, strategies, and methodologies of instruction.

Higher mathematics: Mathematics courses of calculus and beyond.

Listening attentively: Giving careful attention in order to comprehend and communicate ideas, questions, or concerns.

Methodologies: Techniques of instruction, pertaining more to the external structure of teaching.

Student centered: Orientation around the student's perceptual and conceptual world.

Traditional: In mathematics, traditional describes the method of direct instruction. The traditional method of instruction in mathematics is the lecture.

Untraditional: Strategies of instruction other than the lecture method.

Organization of the Study

Beginning with Chapter 1, the Introduction is detailed with descriptions of the following: Statement of the Problem, Methodology, Delimitation of the study, Definition of Terms, and Organization of the entire study.

The historical research of Chapter 2 describes methodologies and behaviors used by successful instructors. Traits discovered to be unsuccessful were noted.

Chapter 3 presents the descriptive research of personal interviews with successful mathematics instructors.

Chapter 4 ties together the Discussion of Findings from the researched studies of Chapter 2 and personal interviews of Chapter 3.

The final chapter, Chapter 5, contains the Summary Recommendations and

Conclusions. With considerations from both the historical and descriptive research, suggestions of effective instruction are presented with Possibilities of Future Research.

Chapter 2

REVIEW OF THE LITERATURE

In this chapter, researched teaching methodologies and teaching behaviors of successful and unsuccessful instructors will be presented. Since college mathematics is, at present, mainly delivered through the direct instruction approach, Chapter 2 will examine the effectiveness of several alternative strategies in hopes of shining light on the many additional modes of instruction which are available. There exist studies that the author presents which are not conducted specifically in college mathematics, yet are included due to the adaptability and applicability of their results to higher mathematics. Though there are various strategies discussed, all focus toward the single goal of enabling instructors to become more effective in promoting student learning through improved teaching.

Strategies of Instruction Through Methodologies

Contained in this section are educational research studies of successful strategies of instruction dating from 1942 to the present. Though most of the strategies mentioned are not widely used in teaching college mathematics, results of these researched strategies promote effectiveness in student learning; thus they form a basis for needed research.

The Use of Lectures

The first method of instruction to be focused on is the lecture. Lecture is the preferred method of instruction in college mathematics. Throughout the writer's educational career in mathematics, she has been taught solely via lectures.

Although the lecture is the "rod and staff" of teaching mathematics, it can be very challenging for instructors to use it effectively for student learning. A lecture contains inherent weaknesses: it negates the suppositions that good instruction should adjust to individual differences, it does not induce activity with respect to the student, and it does not entail forms of feedback to the teacher and student (Gage, 1972). Lack of student involvement induces student passivity, and distraction where their actions can turn to scribbling aimlessly, reading other materials, and nodding asleep.

Research has shown that as lectures continue in length, the students retain less of the material. Hartley and Davies (1978) discovered that students could recall 70 percent of the material presented in the first ten minutes, but could recall only 20 percent of the material presented within the last ten minutes of an hour long lecture. In spite of this unpromising research on the effectiveness of lectures, many instructors firmly believe that it is the only way to teach college mathematics. Thus, for those who adamantly believe in this approach, there are strategies and actions that can be used to strengthen the delivery of lectures.

In the beginning of the lecture, a teacher should arouse the students' curiosity by posing a question or problem, thus initiating a challenge or puzzle to the students. Since a student's capacity for processing information is limited, repetition and pauses should be integrated into the lecture to help students "catch up," thereby avoiding hours of struggle, frustration, and discouragement.

> By making the oral headings visible once again, by recapulating major points, by proposing unanswered questions to be treated in the reading assignments or the future lectures, and by creating an anticipation of the future, the lecturer can help students learn. (McKeachie, 1986, pp. 81-82)

After the body of the lecture the conclusion should follow with a resolution of the question or problem. An effective lecturer always includes enough time for a summary and encourages students to formulate questions or to ask questions. This technique helps students tie concepts and material together, solidifies their mathematical foundation, and aids their mastery of the subject.

Within the body of the lecture, studies showed that frequent questioning caused students to take notes and remember material better. McCarthy (1970) produced a study containing three experimental groups. The first group received training questions every two and a half minutes, while a second and third group received them approximately every five and fifteen minutes, respectively. While the number of questions was equal for all groups, the results showed that the continuous "test-like" events every two and a half minutes brought forth considerable improvement in test performance.

Along with frequent queries, McKeachie (1986), found that students are more likely to be attentive when teachers use variations in their actions. Lectures can greatly be improved with the addition of variety in vocalization, intensity, pace of the lecture, and class discussion. Also adding visual cues such as gestures, facial expression, movement to the blackboard, and using demonstrations or audio-visual aids can help "recruit and maintain attention to the lecture" (McKeachie, 1986, p. 73).

Aside from the auditory and visual aids, what other means are available to help improve lectures? During all the hours of sitting in a lecture in the course of the author's education, she had only one professor who prepared lecture notes in outline form for the students. These outlines were found to be a great aid. Not only did they aid in keeping up with the lecture, but they also enabled students to follow the mathematical concepts more easily. The research of Hartley (1978) and Annis (1981) both focused on note-taking and student conceptualization in lectures. Both researchers implied that although a "skeletal" outline is beneficial to the students, detailed notes cause them to become lackadaisical and passive. A skeletal outline provides the opportunity for the students to fill in important concepts with their own words, aiding their comprehension and retention of the material.

The Use Of Discussions

Thistlethwaite (1960) discovered that National Merit Scholars rank "allowing time for classroom discussion" as an outstanding characteristic of successful teachers (McKeachie, 1986, p. 46).

Even in large lecture halls, successful class discussions can be accomplished. By being involved in a discussion, students become active in their learning, involved with identification of course concepts, and partake in a supportive environment of academic and individual development (Barnes-McConnell, 1980). Discussions enable the students to learn to participate and form "basic levels of trust" within the classroom, thus evolving an openness and mutual inquiry within the class.

> When communication is not all one way, students share leadership of the teaching-learning process as well as responsibility for its success or failure... Students' participation in class is key to promoting

> independent thinking and motivation. Although requiring "considerable instructor spontaneity, creativity, and tolerance for the unknown," it is the means by which students become personally involved in their own education. (Whitman, Spendlove, & Clark, 1986, pp. 31-32)

Studies of these "student-centered" discussions showed increased conceptualization from the students (McKeachie, 1986). Patton (1955), expressed the importance of such student-centered discussions because they brought about a realization to the students that they, themselves, are responsible for their education, and were acceptant of this responsibility. In his study, Patton compared traditional courses to experimental courses that contained no examinations, no lectures, and no reading assignments. In the experimental groups, the students determined "what reading they would do, what class procedure would be used, what they would hand in, and how they would be graded." The results of the study showed that the experimental group "felt the course was more valuable," "showed greater interest in psychology," and "tended to give more dynamic, motivational analysis of a problem of behavior," than the traditional courses (McKeachie, 1986, p. 48).

Another study comparing traditional methods to "participative-action" methods was performed by Gibb and Gibb (1952). Here, the experimental group focused on "sub-grouping methods designed to increase effective group participation," all-the-while the professor continuously decreased in the role of the "decision maker" (McKeachie, 1986, p. 49). The results of the study showed that the experimental group was highly flexible and more insightful when compared to the traditional class.

The Use of Teachers' Questions

Within the research of discussions, it was shown that a professor's questioning challenges the students and enables them to learn more efficiently. Although this is another important concept to promote student proficiency, very few researchers have studied the effects of teachers' questions on students' achievement or behavior. The available studies that have been performed deal with students' behavior as a result of various questioning practices employed by teachers. Hannafin and Osman (1994), looked into the effect of using questions to relate students' prior knowledge and understanding to new material. The researchers hypothesized that this technique would increase the students' problem-solving abilities. The results of their study showed that students receiving this type of questioning responded more frequently, correctly and in-depth to the problems on the exam.

A study conducted by Cordeiro and McDougall (1993) focused on community college students' preparedness for class as a result of the type of questioning the professor used. They found that students expecting questions from the professor on a volunteer basis, as opposed to a random calling by the professor, were less apt to complete the reading assignment. Thus, selecting students at random appears to be the preferred strategy.

Lastly, Dreher and Yopp (1994), targeted their research to determine the difference in students' attitudes towards reading, when teachers directed their questioning to encourage students to ask their own questions about the reading material, rather than responding to teacher-prompted questions. Students responded much more favorably towards the reading in and out of class when they were able to interact with the material, investigating their own questions through the prompting of the teacher. Teachers' ability to ask questions in such a way that students know how

to formulate and answer their own questions, allowing them to be more involved in their reading, is an important form of questioning that can affect students' behavior positively and significantly.

The research conducted on the effects of teachers' questioning on student behavior has not been centered around the same strategies. Those mentioned previously are only a handful of possible strategies that teachers could use to affect students' behavior. Further research still needs to be done regarding what types of questioning approaches will result in higher quality of student responses, attitudes and learning.

The Use Of Groups

The use of group work has been noted and researched, and has been shown to have a positive effect on the students' learning. Research of Terezini, Theophilides, and Lorang (1984) produced a study which evaluated the development of university students' academic skills, specifically critical thinking, assessment, and the ability to apply abstract principles. Results of the study showed that students' degree of classroom involvement was consistently and positively associated with reported growth.

One use of group activity is role playing. McKeachie (1986) describes the main perceived values in role playing are:

1. To enable students the opportunity to practice what they have learned
2. To clarify or explain concepts from the course material
3. To enhance intuition regarding human relations problems
4. To supply a tangible foundation for discussion
5. To perpetuate a fascination with the subject

6. To supply a path in which emotions can be communicated, under the disguise of imagination or make-believe

7. To enhance progressive attention of one's own and other's emotions

Frederick describes role playing as "a powerful learning strategy, guaranteed to motivate and animate most students" (1981, p. 13). Kozma, Belle, and Williams (1978) claimed that the ability to create fascinating and thought-provoking situations is what makes role playing advantageous to the students. It also elicits considerable active participation by the students, thus fostering interest within the course.

In role playing students are working together, thus lessening an environment of competition for the grades. Cooperative achievement can also lessen the tension, self doubt, and anxiety that students feel in the competition of grades. Through role playing, "students given the opportunity to participate actively in the learning process report less stress than those forced into a more passive or helpless mode" (Whitman, Spendlove, & Clark 1984, p. 20).

The Use of Instructional Games and Simulations

With the emergence of a reform movement in calculus, much is beginning to be said about "real world" problems. Concomitant with this concept are new ideas in higher mathematics... games and simulations studies. Although they are very popular with the students, professors are still hesitant to use them, tending to believe that they lack rigor. "Simulations are structured models that imitate reality and are designed to teach specific concepts or enable learners to see the consequences of certain decisions" (Cole, 1982, p. 42).

The unique method of simulations allows students to become involved in roles representative of those in the real world. The students encounter a set of conditions

or determining factors to which they respond and act. A meta-analysis of 93 studies on simulations was performed by Dekkers and Donatti (1981). They found that student attitude and motivation were affected favorably by the simulations, and thus concluded that this strategy was effective.

Compared to simulations, games are less definite in structure; yet they generate more student participation than any other method of teaching. When a game is in "play," all students can be participating and all can be actively learning and teaching at the same time. It is beneficial for students to engage in this method because it stimulates their interests and invigorates learning (Cole, 1982). Compared to the frequent response of listlessness to a lecture, games and simulations prove to be more entertaining, and for some students, more fruitful for conceptualization.

> The learning occurs in discovering fairly quickly the consequences of one's actions or in being confronted with the costs or limits that are imposed upon some social system. More learning can occur if a critique can be prepared after the exercise is concluded. (Cole, 1982, p. 42)

Considering the continuing interests in the methodology of games and simulations the author finds it surprising that few studies of their effectiveness have been completed.

The Use of Students As Teachers

It has been known for some time that small classes are not only more desirable for the professor, but also more effective for the student. Many studies including those of Mueller (1942), Cheydleur (1945), Nachman and Opochinsky (1958), Macomber and Siegel (1957a,b, 1960), Feldhusen (1963), Siegel, Adams, and

Macomber (1960), and Thomas and Fink (1963), have shown individual student attention as one of the many benefits of small classes versus large classes. As California colleges are becoming more and more overpopulated and costly, the expectation for smaller classes is seemingly futile; yet, professors are still expected to be equally effective regardless of the increase in size of their classes.

Using students as teachers has proven to be very effective in student learning. The experience of peer teaching can give the students a sense of ownership of their class, thus reinforcing their motivation to learn. An example of such research can be found in Webb and Grib's (1967) six studies comparing student-led discussions to instructor-led discussion. Out of six studies, two resulted in substantial achievements from the student-led discussions; and an increase in student motivation was noted from both professor and student. Students partaking in the student-led discussions supported this methodology more than the instructor-led discussions. They stated that they were able to express themselves freely and were uninhibited in asking questions. It was also discovered that the students who benefited most were the weaker students. In 1970, Nelson conducted a "peer teaching" study where students serving as proctor-mentors had highly successful outcomes on the Graduate Record Examination.

Another study in this area, conducted by Wortman and Hillis (1967), was on student-taught minicourses. Here, undergraduate students assisted in teaching in large introductory courses. Their task was to develop and prepare a two week "minicourse." The undergraduate students were very enthusiastic about their work and report that teaching the minicourses were very effective towards their own learning.

The Use of Team Teaching

In utilizing the methodology of the minicourse, the concept of team teaching is included. The main focus of team teaching is...

> ...the essential spirit of cooperative planning, constant collaboration, close unity, unrestrained communication, and sincere sharing. It is reflected not in a group of individuals articulating together, but rather in a group which is a single, unified team. Inherent in the plan is an increased degree of flexibility for teacher responsibility, and an invigorating spirit of freedom and opportunity to revamp programs to meet educational needs of students. (Dean & Witherspoon, 1962, p. 4)

Team teaching is not unknown in higher education. For several years, courses containing teams of teachers have been studied in order to observe the effects on student learning. Teachers' combined methodologies, curricula, and continual feedback were shown to provide pertinent, valuable information. This melding of forces produced a highly effective means of learning not only for the students but for the teachers as well. Instructors were able to take advantage of this "buffet" of strengths and effective strategies, which resulted in a very effective and knowledgeable staff.

Bartlett and Byrd (1980) observed how team teaching could enhance the students' academic development. In exploring three undergraduate classes, teams of three teachers performed and completed the course. Along with the exchanging of ideas, they also had time to meet regularly with students to discuss progress and receive helpful feedback. Results of the study showed desirable academic benefits by the experimental groups. Also noted was the "relaxed relationship" among the class

members, where the students exhibited a greater interest in learning. Instructors enjoyed their work more than they had before. "They tended to humanitize the teaching process, becoming less authoritarian and more tolerant of human foibles. Students commented that it helped bridge the gap which existed between students and teachers" (Bartlett & Byrd, 1980, p. 1).

Strategies of Instructional Behavior

Whereas the section entailing methodology relates to the "exterior" aspect or objective teaching techniques of a successful professor, instructional behaviors looks into the "heart" of the successful instructor. Many researchers have studied various teacher behaviors and their effects on student learning. Feldman's research (1989, 1994) identified some 28 different behaviors found in instructors. In the author's reviewing of Feldman's research, principal behaviors found to be most effective in student learning were selected. To provide a comparison, less effective behaviors were also included.

Attentive Listening

One characteristic found to have great importance in effective teaching is attentive listening by the professor to students. Erickson (1984), described three purposes for "active listening":

1. To determine whether one's perception of the student's experience is accurate;
2. To focus attention on the student's need;

3. To further explore the significance of what he/she is explaining.

(1984, p. 100)

When the teachers listen attentively to their students they learn more about the students' thinking process, how students conceptualize, and how students learn from experiences. The teacher can ask questions about the students' reflections, and thus the roles of teacher and student become reversed (Golin, 1990).

In being an advisor, one has to be an attentive listener. Grites (1980) encourages teachers to develop advising skills, claiming that they are the "key" to improving students' performance. With pertinent solid advice, a professor's influence on the students can range from better attitudes, self concept, intellectual and interpersonal development, and higher academic performance, to an increased retention of course material. Student advising is time demanding and requires a special effort from the professor, yet it has the potential to be a major factor in the student's success or failure in their educational career.

Entertaining Versus Teaching

One issue that students believe is an element of good teaching is the ability to entertain. A teacher who can entertain while teaching has the capability to attract and maintain students' attention. This behavior is essential if giving lengthy lectures. To test whether entertainment qualities were effective in a classroom, a study by Naftulin, Ware, and Donnelly (1973) was conducted by using a professional actor. The study proved to show that regardless of material or the relevancy of the material, students responded with high ratings of instruction and claimed that entertainment was very effective in increasing their learning. "Many students rate a good teacher as one who

has a great deal of interest and enthusiasm in the subject, organizes the material well, and is stimulating in presentation" (Centra, 1979, p. 35).

Prominent among entertainment techniques are humor and personal stories. Whitman, Spendlove, and Clark (1986), described the importance of these techniques to help maintain student attention, especially in lectures, promoting student learning.

Enthusiasm

Experiments conducted by Coats and Smidchens (1966), analyzed the efficacy of two behaviorally different instructors. One instructor was quiescent and placid (read from a script, had no eye contact, body gestures, or inflection in tone). The other was enthusiastic (delivered material from memory, had eye contact, body gestures, and also animation). Results of the study found that in comparing the two instructors, greater learning came from the enthusiastic instructor. In a similar study, Mastin (1963) observed 20 instructors. These instructors presented a lecture "enthusiastically" one week and then in an "indifferent" manner the next week. Results of the study showed that of the 20 classes taught enthusiastically, 19 exhibited superior student achievement.

Class Organization, Preparation, Skill, and Clarity

Of the many variations of behaviors displayed by professors, those consistently agreed upon to be effective in student achievement are an instructor's organization, preparation, skill and clarity. An instructor who presents knowledge efficiently, factually, and systematically easily allows the students to conceptualize in an ordered manner, thus providing a more effective foundation from which they can progress toward complex and general cognitive capabilities. "Instructor

organization....involves teaching activities intended to structure material into units more readily accessible for students' long-term memory" (Perry, 1991, p. 26).

In 1992, a study performed by the National Study of Student Learning showed that a teacher's organization, preparation, skill, and clarity prove to be very influential in the development of student's cognitive skills. "Results showed that...the extent to which students judged the overall instruction as high in teacher organization and preparation was significantly and positively associated with end of year development" ("Effects of Teacher," 1994).

Cohen (1981) defines organization/preparation and skill/clarity as two elements of instructional behavior. Examples of organization/preparation are "class time is used well," and "presentation of material is well organized." Examples of skill/clarity are "the teacher gives clear explanations," and "the teacher makes good use of examples and illustrations to get across difficult points." Results of Cohen's meta-analysis in instructor's skill/clarity showed a high positive correlation of .50 with student subject matter achievement. Also, results in instructor's organization/preparation showed a positive correlation of .47 with achievement. In a similar study conducted by Feldman (1989, 1994), results showed that both dimensions of organization/preparation and skill/clarity had high correlations of .57 and .56 with student achievement.

Based on these research findings, there are apparently concrete and consistent effects from organization/preparation and skill/clarity on students' academic achievements. In analysis of these findings, it was suggested that these dimensions also have an effect on a student's common cognitive growth during college.

Moreover, even when controls were made for the number of mathematics, engineering, and natural sciences courses taken, level of

> teacher organization and preparation in overall instruction received during the first year of college also had positive net impacts on standardized mathematics proficiency. Thus, not only does teacher preparation and organization play a major role in students' specific course achievement, its presence in the overall curricular experience also appears to have positive implications for students' general cognitive development during the first year of college.
> (Pascarella, 1994, p. 18)

National Study of Student Learning made further analysis of the study, sampling 2,302 college students. It was discovered that students found the overall teacher behavior of organization/preparation to being significantly and positively associated with their first year cognitive development in mathematics. Within this study it is also discovered that the absence of teacher skill/clarity had a significant and negative effect on first-year outcome (Pascarella, 1994).

Motivating Students

When lectures are the main method of instruction in college mathematics, motivation to learn is unlikely to be found among the students. In the graduate levels of mathematics, where students encounter much stress, motivation can be almost non-existent. It is often very difficult to motivate students in this field.

To motivate students, professors must get to know them. They need to understand where their competence lies, what their conflicting motives are, what their achievement motivations are, and where their curiosity lies. The role model of teachers to the students can also be motivational.

> One of the major sources of stimulation of motivation is the teacher. Probably nonverbal as well as verbal methods are used to communicate such attitudes; that is, facial expression, animation, and vocal intensity may be as important as the words you use.
> (McKeachie, 1986, p. 227)

A student needs to be consistently challenged. Thus, professors need to know where their students' competence lies. If professors dip below the level of their students' capabilities, the students become bored; if professors scale above students' understanding, the students become frustrated. The ideal area for motivation is the "upper" middle ground. Here, a professor can tap into students' curiosity by asking questions. Studies by Berlyne (1954a and b), discovered that by asking questions of students, instead of merely stating and presenting facts, there was improvement in student learning and also an increase in interest and desire to learn more about the concept. In arousing a student's curiosity, it was found that asking questions about already familiar concepts was effective.

At some point in their lives, students may be inspired by certain individuals who become role models and strong motivators for them. For the most part, these personal motivators are teachers. A teacher with enthusiasm and high standards can have a major effect on a student's motivation to learn, as well as perception of and interest in the course material. In 1984, deCharms advised teachers to maximize motivation in the classroom by emphasizing to the students that their expectations were of high teaching efficacy. With this expectancy, students become motivated when they realize much is expected from them and that the teacher believes their goals can be accomplished. "The first and most important thing that teachers must do is to believe that all pupils can be origins, and that teachers can influence pupils in that

direction" (deCharms, 1984, p. 306). DeCharms went on to state that teachers who encourage personal causation have a strong sense of personal teaching efficacy, and that encouragement in turn can have a successful effect on students.

Teacher Feedback

One way for the professor to open and maintain communication with students is to give feedback to them. Students who perform with excellent skills should be informed of that fact so that they know that they are on the right track and should continue on that way. In the same light, a student with poorly developed skills should also be informed. Thus, they are able to focus and work on their deficiencies. Informing the students whether they are properly or not properly accomplishing their work helps them realize whether they are or are not meeting the goals and expectations of the teacher. With feedback comes the comfort of knowing the expectations of the professor and the elimination of guessing and stressing.

Positive feedback or making note of desirable behaviors increases the probability that students will maintain them, yet if they are overlooked they often fade away (Skinner, 1953).

> Good behavior not only deserves attention but requires it as well...positive feedback from faculty that validates good work reduces the stress of uncertainty because standards of excellence are clarified. Recognition for a job well done increases the likelihood that subsequent jobs will be done well too. (Whitman, Spendlove, & Clark, 1986, p. 21)

In a study conducted by Good and Grouws (1977), it was discovered that there was a positive correlation between student effectiveness and teachers who gave immediate feedback.

Student Feedback

Every professor receives student feedback. Usually on the last day of the course, students evaluate the professor, the course, and delivery. All this information can be highly informative to professors. They can discover which strategies were effective and which were undesirable or confusing. Perfecting the strengths and strengthening the weaknesses will help in the instruction of the next session; yet it is too late for the evaluating class to receive such improvements or to feel that they had any influence in the matter. Thus students should be able to provide additional feedback prior to the end of the course.

Although it could be challenging to get students to volunteer feedback, the first month of instruction is the time when evaluation of instruction should be performed . This procedure allows important comments to be evaluated and any hindrances to learning to be confronted before they become serious. "Soliciting feedback from students at least once during the semester informs instructors whether class content or teaching techniques need modification before they become problems" (Whitman, Spendlove, & Clark, 1986, p. 27).

Lowman (1984) described a method of acquiring student feedback. After two to three weeks of instruction, index cards are passed out and comments or questions about the course or professor are to be written. Personal questions are welcomed and the cards need not to be signed unless a reply is requested. The ability to voice an opinion implies to students that the instructor not only finds their thoughts and

concerns important but also respects their privacy. Frequent feedback and listening to students' comments can greatly help professors improve their instruction and also help tailor the course to meet the needs of the class. "Most students take seriously the opportunity to critique instructors, appreciating the chance to share some control" (Whitman, Spendlove, & Clark, 1986, p. 27).

Instructional Strategies of High Sense-of-Efficacy Teachers

> How teachers relate to students influences their methods of discipline and instruction and these methods in turn influence the behavior and attitudes of students. What students do in the classroom influences the behaviors and attitudes of teachers. All these variables are reciprocally related. (Ashton & Webb, 1986, p. 87)

The perception or image of an instructor's sense-of-efficacy result from teachers' explicit and specific beliefs that they can help students to learn (Ashton & Webb, 1986). It has been noted that high sense-of-efficacy instructors have few problems in the management of their classes when compared to those with low efficacy attitudes. It is observed that behaviors of these teachers include high expectations of the student's preparation, organization, work, and respect for one another. The instructors stress the value of class time, the importance of assignments, and the manner in which class time will be well spent. High sense-of-efficacy instructors make it a point to greet their students individually, converse informally with them before or after class, and reinforce those students that are serious about their work and those that master the concepts being taught.

High sense-of-efficacy instructors exhibit "with-it-ness" behavior. They are constantly in tune with their class, know where the students' conceptualization lies,

and consistently stay on task. They filter through the class answering questions and observing student progress, monitoring assignments with feedback, and offering praise and encouragement. They also devote more time to group and individual instruction and demonstrate concern for student learning. All these details describing the high sense-of-efficacy instructor fall into three main categories: relationships with students, classroom management strategies, and instructional methods.

A study conducted by Ashton, Webb, and Doda (1983) indicated that there was a difference in the way that high- and low-efficacy instructors interacted with their students, especially with the low-achieving ones. High sense-of-efficacy behavior appears to exhibit a variety of instructional strategies that mitigate negative influences, are conducive to anticipated accomplishment, and provide a model for classroom behaviors by exemplifying sincere interpersonal relations and scholastic skill. Low sense-of-efficacy behaviors exhibit a variety of instructional strategies which intensify negative influence and lead to student ineffectiveness. Among them are the grouping of students into levels of competence and incompetence and also the defining of classroom behaviors in terms of conflict rather than by positive interpersonal involvements. In these cases, scholastic skills are emphasized, yet they are directed to the students whom the instructor judges competent and meritorious of attention.

The results of this study showed a relationship between the various degrees of efficacy and an instructor's perseverance in achieving a positive emotional environment as well as firm forms of conduct control. From such results, Ashton and Webb (1986) concluded that instructors with high sense-of-efficacy traits promoted: a desire to meet the needs of all students, a belief that students should take the initiative, and the development of a secure and accepting classroom atmosphere.

Thus the hypothesis that student effectiveness is influenced by an instructor's sense-of-efficacy was strongly supported.

Similar studies showed that in mathematics courses there are consistencies in relationships obtained between students' mathematics achievement test scores and the classroom interaction variables. Students who felt secure and accepted performed significantly well in mathematical achievement. Students confronted with negative effects such as criticism and punishment, experienced low mathematics achievement (Ashton & Webb, 1986).

Accessibility

Research among faculty and students found that the most significant difference between effective instructors and their colleagues was the degree to which they interacted with students outside the classroom. Gaff (1973) claims a college professor's likelihood of being regarded as effective is significantly affected by the degree of interaction with the students beyond the classroom.

The research of Terezini, Theophilides, and Lorang (1984) disclosed that the instructors' quality and frequency of teacher-student fraternization, whether during class-time or not, played a major role in the students' academic development. In another study, it was observed that informal faculty-student contact positively associated with educational outcomes such as satisfaction with college, educational aspirations, intellectual and personal development, and academic achievement (Pascarella, 1980). "Positive faculty-student interactions are more than "nice to have": They contribute to the educational objectives of higher learning" (Whitman, Spendlove, & Clark, 1986, p. 29).

Unsuccessful Instructional Behaviors

It goes without saying that an instructor whose behavior exhibits feelings of inadequacy, insecurity, or inferiority jeopardizes student learning. Since these behaviors stem from others such as belligerence, indignity, authoritativeness, ascetically, and irascibility, these expressions can come forth in everyday behaviors. Thus, professors experiencing such feelings can carry their hostility into the classroom, consequently becoming ineffective in promoting student learning.

In a study conducted by Guba and Getzels (1955), a positive correlation was found between personality and student effectiveness; and Rosenzweig (1945) discovered that "extrapunitiveness" (the tendency to blame the environment) correlated to ineffectiveness. "In any case, since expressions of hostility, growing out of aggressive feelings and projected onto students, appear to be basic personality dimensions that undermine the teacher's performance, they must be confronted" (Cohen & Brawer, 1968, p. 25).

When instructors exercise their authority at random, students become resistant to the instructor's demands; and aggression towards the instructor increases (Horwitz, 1958). However, at the other extreme, an unorganized and unpredictable professor can prove to be frustrating to students. If neither a professor's objectives nor the topics or assignments to be covered are clear, students lose their focus. "They miss the sense of control that comes from knowing why the challenges that await them were selected and what rules will govern their evaluation" (Lowman, 1984, p. 36).

Conclusion

In Chapter 2, one encounters studies and opinions of what constitutes the makeup of a successful instructor in college mathematics, the methods they utilize, and behaviors that they exhibit. A variety of methods combined with research shows that there are many effective means to present mathematical material, from the all too familiar lecture to the daring concept of simulations and games.

Though some studies were performed at the secondary level, research shows that many studies can be adapted to fit a range of levels in education.

> Since research designs can be developed at one level and then extended to others, information about the "successful," "effective," "good" kindergarten teacher may be relevant to research on the community college instructor... studies are pertinent to several situations, their findings equally applicable to populations beyond those immediately considered. These are important considerations to keep in mind while recognizing that, in the extensive material devoted to teaching assessment, the evaluation of college teaching effectiveness is a subject which has not received the critical attention it deserves or needs. (Cohen & Brawer, 1968, p. 4)

From experience and analysis of different strategies, research can help professors' instruction become "specialized" and highly effective.

Research has shown that a teacher's organization, preparation, skill, and clarity are some of the behavioral factors leading to a student's successful development of concepts. Some teachers are finding that new instructional strategies of cooperative learning, peer teaching, problem solving, and relation to real world

problems are very motivating for their students. Another importance of these alternative styles of instruction is that there is an improvement of student conceptualization not only in the underrepresented sector, but to all populations of students, thus equalizing the education "opportunity."

Math has been said to be a filter. It filters the women and most minorities out of the system, causing them to be painfully underrepresented in the technical fields (National Council of Teachers of Mathematics, 1992). Today, colleges have a vastly diverse population. Correlating such information with the currently high dropout rate of math majors makes it evident that immediate action needs to take place at the college level to prevent the loss of potential mathematicians.

There needs to be a change in the instruction of college mathematics. If change is not effected in the near future, universities will be risking a high failure rate in this area. There should exist a diversity in methodologies which can effectively meet the educational needs of students of diverse backgrounds. The strategies mentioned in this chapter are proven to be effective motivational techniques. They have been shown to increase learning and decrease phobias, ultimately dissipating the reluctance toward tackling math. Therefore, these successful strategies and methodologies will not only help the students get more out of their education, but will also allow them to become enthusiastic about learning mathematics.

Chapter 3

INTERVIEWS OF SUCCESSFUL INSTRUCTORS

In spite of the research from Chapter 2, there will still remain many mathematics professors claiming that lecturing is the only way to teach mathematics. For this reason, the author brought forth additional research on successful mathematics instruction from college and secondary levels. Personal interviews were conducted with mathematics instructors who were selected on the basis of their reputation for being successful with colleagues and students. The interviews were conducted to discuss with mathematics instructors successful methodologies used in their classrooms. Several professors teaching mathematical concepts of linear algebra, calculus, and complex analysis were interviewed.

Interviews

Professor Scott Farrand, from the California State University, Sacramento, has been teaching mathematics for 14 years. He has taught a variety of mathematics courses. Of particular interest to the author is the special program called the Alliance for Minority Program (AMP). Because of AMP's highly diversified student population and success with student achievement, attention was focused on this program to identify the methods of instruction. In the interview, Professor Farrand discussed his teaching strategy within AMP. AMP students begin in algebra and

work their way to calculus. Professor Farrand remains their instructor for the entire course of instruction.

Professor Farrand begins class with a historical approach, describing how mathematics got started, what math is, and why society has a use for mathematics. He uses cooperative learning and has the students work in groups. He discovered that the students, once they realize that there is a need for higher mathematics, become enthusiastic about the course. In their groups, students interact together and solve problems. This cooperation brings motivation into the classroom, thereby creating an environment conducive to learning. This group interaction also produces peer teaching. Students discuss concepts and work through a problem to find a solution, on their own without assistance from the instructor.

Professor Farrand likes to present the students with real world problems. Since most real world problems do not occur in the classroom, he prepares several group investigations out-of-doors. Such investigations delve into engineering, chemistry, biology , and physics. One example is Setting a Function to Bacteria. This biological study focuses on discovering the growth rate of certain bacteria by using an interferometer, which measures the amount of light that passes through the bacteria. With several investigations, the students can calculate a function which can be applied to the bacteria's growth rate.

Professor Farrand is concerned about students' thought processes and conceptualization. He encourages the students to ask questions, but he claims that, "Just because one student can continually answer your questions, does not mean that the whole class is comprehending" (Farrand, 1995). Thus, he has ways of discovering the students' level of understanding by applying a Socratic dialogue. Intermingled with his cooperative learning and group investigations is a style of jurisprudential

inquiry. When students have queries, he reacts by asking the entire class such questions as: "Who agrees?"; "Who disagrees?"; "Who is willing to argue against or for it?"; "On a scale of one to ten, how sure are you?" (the students respond by raising their hands and showing their scale of one to ten with their fingers. By assessing the students' responses, he is able to determine the students' level of understanding (Farrand, 1995).

Although Professor Farrand finds these strategies successful with student learning, he claims that it would be very challenging to apply them to complex mathematics. When asked if he had any advice for future college mathematics professors in becoming more effective, his recommendation was to establish community with fellow professors.

> Share ideas and sit in on some classes. This is difficult due to the logistics and sometimes awkward, but it can be very valuable! Also, I would highly recommend that all professors look for an opportunity to teach elementary level mathematics. Since the children are more obvious, they tell you right away if they understand or not. This allows the teacher to find out what works and what doesn't. You begin to find out how to create excitement and it prepares you to be brave in your strategies for college. (Farrand, 1995)

The ability to apply and integrate mathematics into different areas can be very motivating to students. Professor Farrand's students work mathematical problems in engineering, chemistry, physics, biology, and other fields. Thus, calculus students, especially those not majoring in mathematics, can become motivated towards their learning when they see why they are learning the methods and how they can be applied to real world problems in their field of study.

It is evident to educational researchers that the instruction of calculus has been unchanged from the lecture method for many years. One professor from the California State University, Sacramento, who believes there needs to be a change in the manner which calculus is presented is Judith Ng. Through her years of teaching college mathematics, Professor Ng has discovered that students are able to do the calculations, yet they really do not understand the concept of when to apply them or what the formula means. Professor Ng claims that the new calculus books appear to be written with "cookbook recipes," yet they really do not explain why and how we use these "recipes." She began some research and discovered a reformed calculus movement called the Harvard Calculus or Calculus Consortium Harvard (CCH). Whereas most math textbooks are about "answers" (and how to get them), CCH focuses on questions, how the questions apply to the real world, and how conceptualization of these questions is beneficial for the student.

In her CCH courses, Professor Ng requires that each student have a graphing calculator (Texas Ti 92). The students work together in understanding how to work the calculator in the first weeks of class. After several hands-on experimentations with the calculator, the students then begin calculus.

> Most calculus books spend much time on how to do the calculations. Instead of using a whole semester to cover this, we now can use the available technology to quickly go through this material and move to the heart of what calculus is and its main ideas. Technology has freed us to focus on the main concepts. Note: This course is rigorous and it contains many word problems. Those students who expect a traditional calculus course have difficulties. (Ng, 1995)

After the group work with the calculator, the instruction moves more towards direct instruction. With the ability to focus on the main concepts, CCH calculus becomes "light and leaner," bringing forth real world problems to the students. Many of these problems each contain several concepts within, whereto the students must proceed to understand each concept and problem solve until mastery of the entire problem is achieved.

The graphing calculator is an example of how technology can aid in mathematical conceptualization. With the advancement of technology and the many fields it encompasses, instructors need to integrate such technical knowledge into their instructional strategies. Professor James Gehrmann from the California State University, Sacramento, believes that with future technology, students will be able to do many things via computers. With networking, students can cooperatively work with other students nationwide, providing a learning environment of problem solving and investigations. Professor Gehrmann is one of CSUS's mathematics professors who teaches algebra and calculus through the use of computer labs.

> The computer programs that I use are Mathematica and Maple. These provide algebraic symbolism, two and three-dimensional graphing, number evaluation, ways of incorporating the graphs and tests, etc. The material that we cover is taught through lectures. It is too complicated to be shown in any other manner. (Gehrmann, 1995)

On the same technological path as Professor Gehrmann is Mr. Gary Preto. Mr. Preto teaches algebra and pre-calculus at Folsom High School. After years of research, he and fellow colleague, Mr. Grant McMicken (a math teacher at San Juan High School), received a grant through Pac Bell (the Intel Project) to promote upper division mathematics in high schools.

Due to a lack of high school students in upper division mathematics, many high schools do not offer courses at these levels; thus the Intel Project enables high school students to sit in on upper division math classes via video conferencing, thereby creating the needed opportunity of continuance in higher mathematics. Another benefit of this technology is that students not only watch the class, but can interact with the teacher and fellow students.

In the instruction of these courses, Mr. Preto uses "untraditional" teaching strategies.

> In my classes I usually have the students work in groups. With the calculus there is much material to cover. One way to cut some of that time is having the groups make their own lessons and present them to the class. The creativity is great and they really have fun with the course. (Preto, 1995)

In Mr. Preto's class there are no written tests. Grades are based on projects, presentations (posters, graphics, overhead displays, creativity, etc.), and knowledge of the material. With students presenting lessons, much of the teacher preparation time is decreased. He therefore can devote more attention to individual students and more adequately meet their needs. In investigations he has the students work with technology as much as they can. Two examples of this technological strategy are as follows:

1. With a graphing calculator (Casio 9800 with three colors), Mr. Preto has the students do statistical projects. With the calculators, they master the concept of data analysis by generating parameters, designing bar graphs, histograms, calculating the mean, median, mode, and standard deviation.

2. Relationship between Sine and Cosine. For this trigonometry problem, students analyze the different graphs, look at the amplitude, periods of vibration, and frequencies.

Then, applying a Socratic approach, Mr. Preto asks probing questions and has the students respond with clarifying answers.

There is much peer teaching and group investigative work in Mr. Preto's class. A bit of advice that he posed for future teachers was to always make time for lessons and strategies.

> One way to increase the class time is to get help. I have several teacher assistants for my classes. I know that I will definitely be needing some assistance with the Intel Project. I already have ten volunteers to help me. The students I have selected are very excited to begin the strategies of the course. I know this project will be successful and that there will be a good communication among the students because they have the enthusiasm. (Preto, 1995)

Another teacher who is well known for his ability to motivate and connect with the students is Mr. Jaime Escalante from Hiram Johnson High School. He applies mathematics to all career fields, both academic and vocational.

> The kids have to be exposed to that...problems you can visualize and work out. We need to teach the kids that the future is the language of mathematics. If the students are exposed to the calculus, they are going to be able to succeed in life. (Escalante, 1996)

In his algebra classes, Mr. Escalante presents various calculus concepts to the students throughout the course. By the time the students are at the calculus level, they have already seen some aspects of it, have some confidence in approaching the

subject, and more importantly, have gotten over the uneasiness of merely just hearing the word "calculus." This integration of concepts is an important teaching strategy, especially with the NCTM Standards (National Council of Teachers of Mathematics, 1992).

Conclusion

In Chapter 3, one encounters strategies and opinions from personal interviews of what constitutes the makeup of successful instruction. Experimentations in various instructional strategies of mathematics have shown that untraditional strategies can be applicable to the higher levels of mathematics; that they have positive effects in student achievement, motivation, and involvement; and that they tend to dissipate student reluctance in attempting mathematics.

Chapter 4

DISCUSSION OF FINDINGS

Chapter 4 ties together the findings from the educational research of Chapter 2 and the personal interviews of Chapter 3; exhibiting instructional strategies found to be effective in student achievement.

Strategies of Instruction Through Methodologies

Many unique strategies in the instruction of mathematics were encountered and researched. The following diverse applications were discovered:

1. the use of discussions
2. the effects of teachers' questions
3. the use of groups
4. the use of games and simulations
5. the use of students as teachers
6. the use of team teaching

The first strategy focused on was the lecture. Though the author desired to point out nontraditional successful strategies, research supports that many professors are unwilling to change from their traditionalistic approaches. Thus, for those who strongly urge the use of lectures, research was included to explore effective methods to lecturing. Recommendations on capturing and aiding student attention and conceptualization were cited. These were: initiating questions; the addition of

pauses; frequent "test-like" events; gestures; facial expression; movement around the classroom; and the availability of lecture notes. Despite the helpful techniques, lecturing remains the least effective strategy for student conceptualization of the material.

It is the author's contention that the use of discussions will help instructors move away from the traditionalistic approach. In class discussions, students can have the opportunity to ask and answer questions, becoming more involved with the discovery of course material. Becoming more active enables students to experience an "ownership" of their class. This ownership perpetuates a feeling of comfort, enabling students to become more insightful with their conceptualization.

Within the concept of the discussion method, research also found that teachers' questioning helped students become involved in their reading, thereby responding more frequently and correctly to questions. This frequent response brought forth in-depth discussions from the students, which increased their problem solving abilities.

Group work and role playing have positive effects on student learning. Tension, self doubt, anxiety, and competition for grades lessen among the students when such cooperative strategies are applied. Because studies show positive correlation between students' degree of classroom involvement and their reported mathematical growth, instructors should seriously consider the implementation of cooperative learning. This strategy has proven to be a powerful tool in learning, highly motivating and animating the students in the classroom.

With educational researchers focusing attention on student participation, the unique methods of games and simulations were studied. Though not common in college mathematics, these methods were found to be very entertaining among

students, resulting in significant improvement in student conceptualization. As such methodologies appear to be conducive to an environment of active learning and teaching simultaneously, there exists a need for experimentation and research of games and simulations in the field of college mathematics.

Research showed that methodologies which brought students into the teacher's role by leading their own discussions, and being active in teaching minicourses or team teaching were very effective in student motivation and conceptualization. Students participating as instructors highly supported this methodology and claimed that it freed them to express themselves and become uninhibited in asking questions. Another benefit of this methodology is that much of the professor's class preparation time is lessened, thus providing more individual time with the students. With this instructor availability, much of the students needs can be met.

Strategies of Instruction Through Behaviors

In researching and identifying strategies of instruction, educational research showed that a high degree of skill in professors did not necessarily ensure success towards student achievement. On the other hand, instructors with entertaining and enthusiastic behaviors and attentive listening may have more success than the highly knowledgeable instructor. In researching the behaviors of instructors, an "inner" framework of successful instruction was discovered. Feldman's research (1989, 1994) identified some 28 different behaviors found in instructors. In reviewing Feldman's research, the author has selected 18 principal behaviors found to be effective in student learning. They are as follows:

1. attentive listening

2. entertaining versus teaching
3. enthusiasm
4. organization, preparation, skill, and clarity
5. motivating students
6. giving feedback
7. welcoming student feedback
8. high sense-of-efficacy
9. accessibility
10. friendliness
11. personal interest in students
12. modification of course to fit the needs of the students
13. treating students as colleagues
14. positive student-teacher relationships
15. permissiveness and flexibility
16. explaining reasons for criticism
17. skill in observing students' reactions
18. knowing students by name.

It is the author's recommendation that instructors in college mathematics should be experienced and comfortable in teaching the strategies listed. In reference to the behaviors, although the first nine characteristics were detailed in the research, it is greatly advised that all instructors pay attention to their "student affecting" actions, and work towards personal improvement, modeling all behaviors listed.

In research of the studies of teacher effectiveness, behaviors and characteristics of instructors which brought forth interest and enthusiasm to the students were: accessibility, organization, preparation, skill, clarity, feedback,

welcoming student feedback, motivation of students, and a high sense-of-efficacy. Common characteristics among these behaviors are constant personal communication between instructor and student, and the teacher's ability to understand the students. Results from educational research on instructional behavior showed a positive correlation between positive instructor-student relationships and students' conceptualization.

Conclusion

While it is common knowledge to mathematics instructors that college mathematics is usually taught directly via lectures, research suggest this method to be highly inefficient for students' conceptualization. Concomitant, research on nontraditional instruction and positive behavior exhibited by mathematics instructors provided results of high efficacy in student conceptualization in mathematics. In researching successful strategies of instruction it was discovered that valuable information on the effectiveness of instruction existed in the student evaluations on instructors and mathematics courses. These evaluations, if considered, enable instructors to effectively meet the needs of the students; promoting student motivation and growth in the mathematics courses.

Chapter 5

SUMMARY AND RECOMMENDATIONS

Summary

The population of college students is becoming more diverse. Yet, while there is the increase in diversity among the collegiate populace as a whole, there remains an ever-decreasing number of mathematics majors. Many of these students being filtered out are women and most minorities. Educational research indicates that ineffective instruction is the reason for the high attrition rate in mathematics.

While it is common knowledge to mathematics instructors that college mathematics is usually taught directly via lectures, results from studies suggest this method to be highly ineffective for students' conceptualization. The focus of this research was to explore successful teaching strategies for college mathematics. A variety of untraditional methods and instructional behaviors positively correlate to successful student achievement, conceptualization, and motivation in mathematics.

Recommendations

If the goals of universities, specifically California State University, Sacramento, are to "offer high quality academic programs, achieve recognition for superior accomplishments in teaching and learning, to serve a qualified, diverse

student population and facilitate timely graduation" (CSUS, 1996), then it is evidently clear that there is a need for research not only in the instructional methodologies of college mathematics, but also in the curriculum. With educational research and evaluation on instructional strategies, quality and equal opportunity in education can be focused on and ultimately heightened.

If studies show that the quality of college mathematics instruction contributes to the decline of students majoring in science, mathematics, and engineering, then a direct approach to assess the instruction is to survey and evaluate the students. With "ringside seats", students contain a wealth of "researchable" information about successful instruction. By utilization of student evaluations, the information gathered could create many studies, causing great strides in the proficiency of college mathematics. Currently, there exist conflicting reactions from traditionalistic professors in mathematics. These professors insistent upon their ways, avoid alternative strategies that could improve their instruction.

Traditionalistic professors become a serious road block in the quest for reform. Though expected to be responsible for experimentation and research in more effective strategies, many, if not most professors, believe that with the complex mathematics, direct instruction is the only way. One professor from Stanford claimed,

> The goal of many of these new (programs) is not necessarily to solve the problem, it's to think about the problem. I don't buy that. If an engineer is going to figure out how much lift you need in an airplane, he'd better get the right answer. (Sacramento Bee, 1996, p. A12)

Another pessimistic view claims "institutions should refrain from making any radical transformation of teaching" (Mayhew 1979, p. 214). It is traditionalistic attitudes

such as these that cause difficulties to the advancement of teaching twentieth century mathematics.

Despite the pessimism, the author is optimistic towards the future for the instruction of college mathematics. Where once professors claimed everything but a lecture was unrealistic, there now exist a few who are beginning to conduct their own research in different strategies for example, the calculus reform movement. There was much resistance; yet with some adaptable ideas from other studies, and experimentation, there now exist some positive effective results, causing interest to be sparked. Where they once sat idly in a calculus lecture for hours, students are now being active with participative group work, peer teaching, and investigative work with real world problems. The author's research has found strategies of instructional improvement and has shown that they can be applied to college mathematics.

With the adoption of such methods, the needs of the students will be met, students will have a greater conceptualization, student edification will increase, and most importantly, students may become motivated and enthusiastic towards their learning in college mathematics. Such positive responses will ultimately result in a decrease in the attrition rate of mathematics majors, thereby bringing a greater percentage of the populace and greater degree of diversity into the college mathematics field.

Conclusion

In review of the studies and interviews presented on the successful teaching strategies of college mathematics, it is evident that "nontraditional" strategies can be successfully applied in the college field. From the author's personal experience,

observations, and research, it is highly recommended that such strategies in the instruction of college mathematics be encouraged, implemented, and practiced.

Possibilities of Future Research

This study has presented several suggestions for instructional edification in college mathematics. It is hoped that reform in this area will better suit the educational needs of the students, enabling them to be enthusiastic and successful in mathematics. Presently, there have not been many studies conducted on this subject, thus it is anticipated that this research has presented some ideas for possible experimentation in the instruction of college mathematics. Also note, with current research focused on secondary levels, this study shows the possibility that findings relating to secondary mathematics teaching may also apply to the college level.

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