Perceptions of graduate teaching assistants and their students on collaborative learning in reform calculus and its relationship to instruction and achievement
by Beth Ann Kilday

A thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Education in Secondary Curriculum and Instruction
Montana State University

Abstract:
The major problem of this study was to determine how effective university graduate students teaching reform engineering calculus were in using collaborative learning. The major objectives of this study were to . determine the separate and collective contributions of: (1) the class section, (2) students' perceptions of their instructors' views of collaborative learning, and (3) students' perceptions of collaborative learning, in explaining variability in student mathematical achievement. Quantitative and qualitative research methods were used in this study.

Six graduate teaching assistants who were teaching a first semester engineering reform calculus class were trained in the use of collaborative learning prior to the study. Participants reported that the two-day intensive workshop was useful. All the instructors were required to use collaborative learning as a teaching technique.

The study determined that there were statistically significant relationships between: , (1) students' final examination scores, students' perceptions of collaborative learning, and the class section; and (2) students' final examination scores and students' perceptions of collaborative learning. There was a statistically significant difference in five classes between instructors' and students' perceptions of collaborative learning. Four of the instructors had positive perceptions of collaborative learning and two had negative perceptions. There was no statistically significant change in students' and instructors' perceptions of collaborative learning during the semester, although qualitative data showed some changes. Three instructors taught calculus in manners consistent with their perceptions and three did not. Students were generally positive about small group work in five classes and negative or neutral in one.

Recommendations for successful implementation of collaborative learning in reform calculus courses are to: (1) educate instructors in the philosophy of collaborative learning, (2) provide extended professional development for instructors teaching with collaborative learning, including ongoing interaction between graduate teaching assistants and experienced reform calculus instructors.

PERCEPTIONS OF GRADUATE TEACHING ASSISTANTS AND THEIR STUDENTS ON COLLABORATIVE LEARNING IN REFORM CALCULUS AND ITS RELATIONSHIP TO INSTRUCTION AND ACHIEVEMENT

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This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ABSTRACT

The major problem of this study was to determine how effective university graduate students teaching reform engineering calculus were in using collaborative learning. The major objectives of this study were to determine the separate and collective contributions of: (1) the class section, (2) students' perceptions of their instructors' views of collaborative learning, and (3) students' perceptions of collaborative learning, in explaining variability in student mathematical achievement. Quantitative and qualitative research methods were used in this study.

Six graduate teaching assistants who were teaching a first semester engineering reform calculus class were trained in the use of collaborative learning prior to the study. Participants reported that the two-day intensive workshop was useful. All the instructors were required to use collaborative learning as a teaching technique.

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

Introduction

Calculus has been and will continue to be a central part of the college curriculum (Mathematical Association of America (MAA), 1986, p. iv). It is of major importance to students pursuing engineering, science, mathematics, and other mathematics-related careers.

A conference at Tulane University in January, 1986, prompted a discussion among mathematics educators concerning calculus instruction. Participants charged that "calculus was not being taught in a way befitting a subject that was once the culmination of the secondary mathematics curriculum and the gateway to collegiate science and mathematics" (MAA, 1993, p. vii). Many students in collegiate calculus either did not complete the course or failed to achieve a "C" grade or better and many students who completed the course with high marks failed to understand the calculus concepts adequately. MAA members stated that there were many variables concerning the delivery system that were responsible for the low

grades and lack of understanding (MAA, 1993, p. vii). Classes that were too large, professors who taught calculus using "cookbook" procedures, and inadequately trained teaching assistants whose main concerns were their own graduate programs are all listed as major problems affecting calculus instruction (MAA, 1993, p. vii). For many students, calculus was a mechanical process based on rules rather than concepts.

The mathematics educators attending the Tulane conference began to seriously rethink collegiate calculus instruction. Those mathematics educators became convinced that changes in the instructional delivery system of collegiate calculus were necessary. Projects were developed with funds from the National Science Foundation (NSF, 1993) and other sources that focused on conceptual calculus emphasizing graphical, numerical, and algebraic representations of the calculus ideas. Traditionally, calculus instruction had depended on lecturing and emphasized algebraic or algorithmic processes. The traditional method of calculus teaching began to be replaced by an emphasis on graphical and numerical analyses of the calculus concepts in addition to algebraic representations. Since traditional calculus textbooks include a large

number of topics, it is difficult to study them in depth. Thus, it was the goal of the Mathematical Association of America (MAA), in their book Toward a lean and lively calculus, to emphasize that future calculus courses "contain fewer topics" but have "more conceptual depth" (MAA, 1986, p. v). The Calculus Consortium based at Harvard University constructed a reform calculus textbook that incorporated these suggestions (Hughes-Hallet et al., 1994a). The reform calculus textbook authors also changed the sample problems, concept explanations, and homework problems to fit the mold demanded by the Tulane Conference participants. This textbook change accompanied a change in instruction. Homework problems in reform calculus textbooks are not as cut-and-dried nor template-like as problems in traditional textbooks (Hughes-Hallet et al., 1994a, p. xiv). Reform calculus textbook authors stress that students find it helpful to discuss homework problems in small groups (Dubinsky & Schwingendorf, 1992; Hilbert et al., 1994; Hughes-Hallet et al., 1994a; Smith & Moore, 1993).

Calculus emphasizes strategies including student-centered learning, use of technology, applications, and emphasis on concepts and problem solving. These strategies demand different ways that

content is presented by helping students to be active participants in the classroom. Reform calculus also encourages students to be responsible for their own learning. Although reform calculus often has different meanings for different mathematics educators involved in the reform effort, there do seem to be some components common to all of the major reforms. The paradigm shifts often emphasized include: making use of several different means of assessment, use of computers and/or graphing calculators, modeling and real world application problems, and use of collaborative learning techniques (Tucker & Leitzel, 1995, p. 5). Another component common to the major reforms is instructing interactively by having instructors question students and promote class discussion (Hughes-Hallet et al., 1994b). These changes are generally recommended to improve calculus instruction.

Another important aspect of reform calculus is allowing students to verbalize their ideas of the calculus concepts. Student verbalizations of calculus concepts enable instructors to observe the students within the classroom setting as they acquire needed calculus skills and concepts. Collaborative learning activities and projects also allow students to verbalize their thoughts concerning

the calculus concepts and skills (Hughes-Hallet et al., 1994a).

Calculus classrooms utilizing: (1) alternative assessments, (2) appropriate use of technology, (3) collaborative learning, (4) students' conceptual verbalizations, (5) less traditional lecture with instructional delivery systems that promote interactive classrooms and multiple representations of the concepts, and (6) greater use of real world problems, are the major pedagogical reforms often recommended in order to assist students in learning and retaining calculus concepts.

A survey (conducted in the Spring semester, 1994) of collegiate mathematics departments found that 68% of 1048 responding mathematics departments in the United States were engaged in reform calculus efforts (Tucker & Leitzel, 1995, p. 1). In April, 1994, mathematics departments at 104 colleges and universities in seven northwestern plains states received a questionnaire concerning reform calculus. The STEP (Systemic Teacher Excellence Preparation) and SIMMS (Systemic Initiative for Montana Mathematics and Science) projects at Montana State University-Bozeman initiated this activity in an effort to ascertain the regional institutions involved in the reform calculus effort. Results indicated that approximately 48%

of the 65 responding institutions were currently involved in some type of calculus reform effort. Reform calculus seems to be gaining widespread popularity and acceptance. Textbook publishers report a notable increase in reform calculus textbook sales between 1993 and 1994, indicating a shift from traditional instruction to reform instruction in calculus (Tucker & Leitzel, 1995, p. 27).

Despite the increased awareness of reform calculus objectives among collegiate faculty, many instructors are hesitant to adopt teaching methods that are unfamiliar to them regardless of whether the methods have been proven successful. A teaching technique that instructors are hesitant to use when teaching collegiate calculus is collaborative learning. Collaborative learning is defined as students working in small groups, solving problems, discussing issues, and attempting to reach individual or group conclusions (Slavin et al., 1985). Collaborative learning is not normally used in traditional college mathematics teaching. The National Council of Teachers of Mathematics (NCTM) (1989) promotes teaching strategies, such as collaborative learning, that increase students' ability to work with others when solving problems. Also, many employers in the business and engineering fields expect employees to be able to solve

problems using a team approach. Mathematics instructors (i.e. graduate teaching assistants) who teach collegiate calculus could have some perceptions concerning collaborative learning that can affect their instructional practice, their students' perceptions of collaborative learning, and student achievement. Research indicates that teachers with particular views about specific mathematics instruction ideas often exhibit those perceptions in the classroom during instructional practice (Brown & Baird, 1993; Kagan, 1992; Peterson, 1988; Thompson, 1984). Identifying instructors' professed views about collaboration in the calculus classroom can assist mathematics instructors in adapting their teaching to the goals of reform calculus. Also, reform calculus courses utilizing collaborative learning, technology, and conceptual understanding can aid in increasing the rate of success of students who may not have succeeded in traditional calculus courses (Hughes-Hallet et al., 1994c).

Statement of the Problem

For the purposes of this study, collaborative learning is defined as students working in small groups, solving problems, discussing

issues, and attempting to reach individual or group conclusions (Slavin et al., 1985). Collaborative learning techniques are now being utilized in many reform calculus classes (Dubinsky & Schwingendorf, 1992; Hilbert, et al., 1994; Hughes-Hallet, et al., 1994a; Smith & Moore, 1993). Mathematics educators are in need of findings supported by research that indicate whether or not classroom collaborative learning techniques actually assist students in learning the calculus concepts. Also, calculus instructors (i.e. graduate teaching assistants) can have different views of collaborative learning. Identifying these perception differences of collaborative learning and determining the relationship between instructors' views of collaborative learning and student achievement can be of interest to mathematics educators.

The problem of this study was to determine the separate and collective contributions of: (1) the calculus section effect (the effect of students' calculus section in which they were enrolled), (2) students' perceptions of collaborative learning, and (3) students' perceptions of their instructor's views of collaborative learning, in explaining variability in student mathematical achievement on a comprehensive final examination in a reform calculus course that

utilized collaborative learning techniques. Instructors' actual teaching practice utilizing collaborative learning was also examined and related to instructors' and students' perceptions. All calculus instructors in the study were graduate teaching assistants at Montana State University-Bozeman.

The dependent variable was student achievement in the reform calculus course measured by a final comprehensive examination. Independent variables were the calculus section effect, students' perceptions of collaborative learning, and students' perceptions of their instructors' views of collaborative learning. The independent variables were measured using collaborative learning questionnaire instruments in Likert form.

The study was conducted during the Fall semester, 1995, at Montana State University-Bozeman in six sections of first semester engineering calculus (Calculus and Analytic Geometry I). Six graduate teaching assistants were participants in the study, as well as their respective classes of students. Each class varied in size from 25 to 40 students (students who finished the course). One hundred and thirty-three students were involved in this study.

Need for This Study

Collaborative learning is a relatively new term in mathematics education. For the purposes of this study, collaborative learning is defined as students working in small groups, solving problems, discussing issues, and attempting to reach individual or group conclusions (Slavin et al., 1985). Research studies addressing this topic should be undertaken (Brody & Hill, 1991; Grouws, 1992). A survey (conducted in the Spring semester, 1994) of mathematics departments found that 68% of 1048 responding collegiate mathematics departments in the United States were engaged in reform calculus efforts (Tucker & Leitzel, 1995, p. 1). In April, 1994, mathematics departments at 104 colleges and universities in seven northwestern plains states received a questionnaire from STEP concerning reform calculus. Results indicated that approximately 48% of the 65 responding institutions were currently involved in some type of calculus reform effort. Reform calculus seems to be gaining widespread popularity and acceptance. Textbook publishers report a notable increase in reform calculus textbook sales between 1993 and 1994, indicating a shift from traditional instruction to reform instruction in calculus (Tucker & Leitzel, 1995, p. 27).

Mathematics educators are questioning whether or not strategies recommended in the calculus reforms will improve student retention and success rate. Collaborative learning is an important component of many current collegiate reform calculus projects (Dubinsky & Schwingendorf, 1992; Hilbert et al., 1994; Hughes-Hallet et al., 1994a; Smith & Moore, 1993). Studying the relationships among: (1) instructors' perceptions about collaborative learning, (2) students' perceptions of their instructor's views of collaborative learning, (3) students' perceptions (understanding and opinions) of collaborative learning, (4) instructors' actual teaching practice, and (5) student mathematical achievement on a comprehensive final examination in a reform calculus course utilizing collaborative learning techniques, could be of importance to the collegiate mathematics education community. This new and different way of instructing calculus is important to mathematics educators because of their interest in improving student success rate while reducing the student withdrawal and failure rates in calculus (MAA, 1986). Mathematics instructors (i.e. graduate teaching assistants) who teach collegiate calculus hold varying perceptions concerning collaborative learning. These perceptions can affect how they instruct calculus.

Recognizing perceptions about collaborative learning can assist mathematics graduate teaching assistants in adapting their teaching so they best support the goals of reform calculus.

While working as a research assistant with the Systemic Teacher Excellence Preparation (STEP) Project at Montana State University-Bozeman (MSU-Bozeman) during the 1994-95 academic year, this researcher was assigned to work with the implementation phase of the reform calculus textbook in first semester engineering calculus (Calculus and Analytic Geometry I). This textbook was developed by the Calculus Consortium based at Harvard University (Hughes-Hallet et al., 1994a). The course is required for secondary mathematics education students. The implementation and effectiveness of collaborative learning in first semester engineering calculus was given special attention because of its importance to successful calculus reform. Also, as calculus instructors model collaborative learning techniques in the classroom, the STEP Project Directors expect future secondary mathematics teachers to teach in ways similar to the way they were taught. Therefore, they are more likely to use similar teaching methods in their future classrooms.

The STEP Project promotes those instructional techniques relevant to the goals of reform calculus.

A Pilot Study

Collaborative learning is an instructional technique that incorporates a variety of classroom strategies which increase student participation in the learning process. Students working in small groups, solving problems, discussing issues, and attempting to reach individual or group conclusions are engaging in collaborative learning (Slavin et al., 1985). The STEP program advocates that these strategies need to be experienced by future educators to insure proper use of collaborative learning when they become the instructors. Collaborative learning workshops, facilitated by appropriate consultants, can be conducted to educate mathematics instructors (i.e. graduate teaching assistants) about this instructional method. Two collaborative learning workshops were conducted during the 1994-95 school year in the MSU-Bozeman mathematics department for the instructors of first semester engineering calculus (Calculus and Analytic Geometry I). The agenda for the Fall semester, 1995, workshop (Appendix A) was modified (using

information gathered at the two previous workshops) to fit the needs of the study for collection of data. The amount of time spent on collaborative learning instructional techniques and implementation was greater than that of the previous workshops. Pertinent information and research articles were given to the workshop participants (i.e. first semester engineering calculus instructors).

During the 1994-95 school year at MSU-Bozeman, an observation checklist for measuring instructors' actual teaching practice in first semester engineering calculus was constructed from an existing checklist located in a middle school handbook (Forte & Schurr, 1993). This instrument was then piloted in first semester engineering calculus and modified during the academic year. The checklists were modified and piloted in two sections of first semester engineering calculus during the Summer semester, 1995, at MSU-Bozeman. Two professional mathematics and science educators validated this effort. Final modifications were made to the observation instrument prior to collection of data during the Fall semester, 1995 (Appendix B).

Collaborative learning questionnaire instruments used to gather data about instructors' perceptions of collaborative learning,

students' perceptions of their instructors' views of collaborative learning, and students' perceptions of collaborative learning were piloted in two sections of first semester engineering calculus during the Summer semester, 1995, at MSU-Bozeman. Three professional mathematics and science educators provided modifications of the instruments (student and instructor questionnaires) and validated the revisions during the Spring semester, 1995. A MSU-Bozeman statistician and statistics consultant with the Office of Applied Research Services assisted this researcher in testing these instruments for reliability during the Summer semester, 1995. The final instructor and student collaborative learning questionnaire instruments are found in Appendices C and D, respectively.

Three professional mathematics and science educators modified the instructor interview instrument during the Spring semester, 1995. The revised instrument was piloted during the Summer semester, 1995, in two sections of first semester engineering calculus. Following final modifications to the instructor interview instrument the student interview instrument was constructed and modified before reaching its final format. Two professional mathematics and science educators oversaw the revisions of these

two instruments. Appendices E and F show the instructor and student interview instruments, respectively.

Definition of Terms

For the purpose of this study, the following definitions were used:

actual teaching practice - instructional methods and techniques clearly observed during the instruction of first semester engineering calculus. Techniques could be affective (i.e. affect attitude), cognitive (i.e. affect intellectual ability), verbal (i.e. oral or written statements), or subtle (i.e. body movements and expressions). Weekly observation checklists were used to observe instructional methods and techniques in each section of first semester engineering calculus involved in the study.

calculus section effect - the effect of calculus section on students' final examination score. Participating students in the study were enrolled in six different calculus sections. The calculus sections were instructed by graduate teaching assistants with varied perceptions and instructional strategies of collaborative learning.

collaborative learning - to work jointly with two or three other calculus students to gain insight about a particular problem or situation (Merriam-Webster, 1993). Students help each other in exchange for reaching their own personal goals, rather than working toward a common, shared goal (Slavin et al., 1985). For the purposes of this study, collaborative learning is students working in small groups, solving problems, discussing issues, and attempting to reach individual or group conclusions (Slavin et al., 1985).

collaborative learning workshop - workshop designed to address collaborative learning techniques that were intended to work successfully in the calculus classroom. Collaborative learning consultants and users volunteered information (tips and tools) to first-time users that were intended to assist them with group dynamics and pedagogy. Participants experienced collaborative learning and discussed its potential use in their own classrooms.

first semester engineering calculus student - students enrolled in the first semester engineering calculus course, entitled Calculus and Analytic Geometry I (MATH 181), at MSU-Bozeman. Topics included: functions, limits, continuity, differentiation, applications of

the derivative, curve sketching, analytic geometry, integration, and applications of the integral (MSU-Bozeman, 1994).

graduate teaching assistant - mathematics graduate student at MSU-Bozeman contracted to instruct one of the multiple sections of first semester engineering calculus. Graduate teaching assistants met weekly with the supervisor of the course to discuss daily lectures, lessons, use of technology, group work, homework, and common testing procedures. Instructors were free to assess alternatively (quizzes, presentations, portfolios, projects, etc.). Instructional techniques varied between instructors. All instructors involved in this study were graduate teaching assistants.

perceptions - beliefs, conceptions, or opinions of humans. Perceiving or believing something is different than knowing. The difference between perceptions and knowledge is that perceptive believers are aware that others may think differently (Thompson, 1992).

reform calculus - emphasizes strategies including student-centered learning, use of technology, applications, and emphasis on concepts and problem solving. Reform calculus classrooms utilize alternative assessments, technology, collaborative learning, students'

conceptual verbalizations, less traditional lecture, and instructional delivery systems that promote multiple representations of the concepts (MAA, 1986). The Harvard reform calculus textbook was used in all the classes involved in this study (Hughes-Hallet et al., 1994a).

student calculus achievement - numerical score on a final comprehensive examination given to all first semester engineering calculus students at the end of the Fall semester, 1995, at MSU-Bozeman.

view - an opinion, judgment, or belief colored by feeling or bias of the holder (instructor or student) (Merriam-Webster, 1993).

Questions to be Answered

As related in the Statement of the Problem, this study determined the separate and collective contributions of: (1) the calculus section effect, (2) students' perceptions of collaborative learning, and (3) students' perceptions of their instructors' views of collaborative learning to student mathematical achievement on a comprehensive final examination in a reform calculus course utilizing collaborative learning techniques. Instructors' actual teaching

practice utilizing collaborative learning was also examined and related to instructors' and students' perceptions. All calculus instructors in the study were graduate teaching assistants at Montana State University-Bozeman. Several questions stemming from the problem statement are posed in this section.

Questions to be answered in this study are as follows:

1. How do each of the independent variables, (1) the calculus section effect, (2) students' perceptions of collaborative learning, and (3) students' perceptions of their instructors' views of collaborative learning, *collectively* contribute to the variability of the dependent variable, student mathematical achievement, on a comprehensive final examination in reform calculus?
2. How do each of the independent variables, (1) the calculus section effect, (2) students' perceptions of collaborative learning, and (3) students' perceptions of their instructors' views of collaborative learning, *separately* contribute to the variability of the dependent variable, student mathematical achievement, on a comprehensive final examination in reform calculus?

3. Do instructors' perceptions of collaborative learning change throughout the semester in the reform calculus course?
4. Do students' perceptions of collaborative learning change throughout the semester in the reform calculus course?
5. Do students' perceptions of their instructors' views of collaborative learning reflect their instructors' stated perceptions?
6. Are instructors' perceptions of collaborative learning reflected in their actual teaching practice?
7. Do instructors feel that the collaborative learning workshop met their needs?

Review of the Literature

Collaborative Learning in Mathematics

Despite the increased awareness of suggested teaching strategies (e.g. collaborative learning) recommended in the calculus reform movement, instructors (i.e. graduate teaching assistants) are usually hesitant to adopt a different teaching method when it is unfamiliar to them. Collaborative learning is an example of a teaching strategy that instructors are unlikely to use in collegiate

calculus unless they are convinced of its value for improving student success. Collaborative learning and its relationship to student learning in calculus is the major component of this study.

Collaboration can be defined when "two or more individuals help each other in exchange for reaching their own personal goals, rather than working toward a common, shared goal" (Slavin et al., 1985, p. 27). This study defined collaborative learning as students working in small groups, solving problems, discussing issues, and attempting to reach individual or group conclusions. Cooperative learning is similar to collaboration with the inclusion of working toward a common, shared goal. This study investigated collaborative learning. However, most of the published literature has focused on cooperative learning.

The comparison between collaboration, cooperation, and small group work needs to be addressed. The literature speaks of each of these three concepts. Cooperative learning is students working together to accomplish shared goals (Johnson et al., 1991). Students collaboratively engage in activities that are "beneficial to themselves and to all other members of the group. Cooperative learning is the instructional use of small groups so that students work together to

maximize their own and each other's learning" (Johnson et al., 1991). Students working in small groups are collaborating but are only cooperating if they are trying to accomplish shared goals. Appendix I shows a diagram of how this researcher views the comparisons between collaboration, cooperation, and small group work.

Reform calculus is a method of teaching calculus that requires collaborative learning. Collaboration is not often used in traditional mathematics teaching at the collegiate level. Many mathematics reform studies are calling for increased use of collaborative learning methods in mathematics (Kaput & Dubinsky, 1994). Results from a study conducted in 1977 by Brechting and Hirsh found that introductory calculus students engaging in small group discovery learning do improve their calculus achievement scores. Studies conducted in collegiate remedial mathematics courses that utilized small group learning showed similar results (Chang, 1977; Dees, 1991). Davidson (1990) outlines several strategies for small group work in collegiate mathematics classes. He summarized the research by saying that students who are involved in small group work perform just as well if not better than their counterparts taught using the traditional method (Davidson, 1990). "Advantages of

cooperative groups include: active student involvement; opportunity to communicate mathematically; a relaxed, informal classroom atmosphere; freedom to ask questions; a closer student-teacher relationship; high level of student interest; more positive student attitudes; and opportunity for students to pursue challenging mathematical situations". (Kaput & Dubinsky, 1994).

The National Council of Teachers of Mathematics (NCTM) (1989; 1991) promotes teaching strategies, such as collaborative learning, that increase students' ability to work with others when solving problems. Also, many employers (e.g. business and engineering firms) expect employees to be able to work with others to reach company goals. This researcher believes that mathematics instructors who teach collegiate calculus have some perceptions concerning the use of collaborative learning in their classrooms that affect their teaching pedagogy (i.e. use of cooperative or collaborative learning), their students' perceptions of collaborative learning, and their students' achievement. Research indicates that teachers who have particular views about specific mathematics instruction ideas often exhibit these perceptions in the classroom during instructional practice (Brown & Baird, 1993; Kagan, 1992; Peterson, 1988;

Thompson, 1984). Identifying instructors' perceptions about collaborative learning can assist them in adapting their teaching to the goals of reform calculus. Institutions that offer reform calculus courses that utilize collaborative learning can help in increasing the success rate of students.

Collaborative Learning and Instructional Practice in Mathematics

Mathematics instructors (i.e. graduate teaching assistants) who teach collegiate calculus hold varying perceptions concerning collaborative learning. These perceptions can affect how they teach calculus. Finding any preconceived views about collaborative learning can assist mathematics instructors in adapting their teaching so they are consistent with the recommendations of reform calculus. Once instructors' perceptions about collaborative learning in reform calculus are determined, the researcher can describe the ways in which instructors model collaborative learning methods and describe the instructors' teaching methods as seen from their perceptions, their students' perceptions, and through actual classroom observations.

The research that was analyzed for this review addressed three main areas: teachers' perceptions about mathematics and mathematics instruction, the relationship between teachers' perceptions of mathematics teaching and their observed instructional practice, and teachers' perceptions about collaborative learning in mathematics. Research in the area of teachers' change in beliefs was also analyzed.

Teachers' Perceptions About Mathematics and Mathematics Instruction

Harvey, Prather, White, and Hoffmeister (1968) examined how teachers' beliefs about mathematics instruction affected classroom atmosphere and student behavior. Although this is a dated study, they found that correlations did exist between teachers' professed perceptions and their instructional practices. The "This I Believe" (TIB) test (developed, tested, and used by Harvey) was used to gather information on instructional beliefs. Following TIB testing, teachers were observed by the researchers. It was found that teachers' beliefs generated consistent and predictable behaviors in the classroom (Harvey et al., 1968).

Peterson, Fennema, Carpenter, and Loef (1989) examined teachers' beliefs about mathematics and mathematics instruction and noticed that teachers vary widely in their belief constructs. Correlational comparisons were examined between teachers' belief constructs and their professed instructional practices using a survey instrument. Positive correlations were found to exist. This study supports the need for examining teachers' perceptions about mathematics and mathematics instruction and how these perceptions relate to instructional practice (Peterson et al., 1989).

The Relationship Between Teachers' Perceptions of Mathematics Teaching and Their Observed Instructional Practice

Studies conducted by Collier (1972), Cooney (1983), Grant (1984), Kesler (1985), and Sullivan & Leder (1992) dealt with the relationship between mathematics teachers' stated beliefs of mathematics instruction and their actual teaching practice. Results indicated that teachers' stated beliefs tend to coincide with their actual teaching practice unless ambivalence of belief terminology (Collier, 1972) or conceptions of expressed belief statements (Grant, 1984; Kesler, 1985) were misinterpreted by the teachers.

Thompson (1984) and Schwartz and Riedesel (1994) focused on the relationship between teachers' perceptions of mathematics teaching and their observed instructional practice. Thompson (1984) used a qualitative case study approach while Schwartz and Riedesel (1994) utilized questionnaires to collect data and multiple regression to analyze the data. Schwartz and Riedesel combined correlation, descriptive, and regression techniques. Thompson's study thoroughly examined three elementary mathematics teachers by using the case study approach while Schwartz and Riedesel (1994) investigated 140 elementary educators self-reporting their beliefs and practices. Detailed observations were conducted by Thompson (1984) while self-professed instructional practices were evaluated in the Schwartz and Riedesel (1994) study. Both studies found that there did exist a correlation between teachers' professed beliefs about mathematics teaching and their instructional practice. Thompson (1984) found that there exists a complex relationship between beliefs and practice. Schwartz and Riedesel (1994) determined that correlations did exist between teachers' beliefs and instructional practice, but not between teachers' mathematical understanding and instructional practice. Researchers caution

readers that just because teacher educators focus on strengthening teachers' mathematical content knowledge, it does not mean that this will help teachers teach according to the Standards (1989).

Teachers' Perceptions About Collaborative Learning in Mathematics

The Thompson (1984) and Schwartz and Riedesel (1994) studies both exhibit findings that show teachers' beliefs influence their instructional practice. Neither study noted collaborative learning as an instructional technique. However, studies examining instructors' beliefs of collaborative (or cooperative) learning have been found. Although there were few studies found examining collaborative learning, one study (Brody & Hill, 1991) examined teachers' beliefs about cooperative learning and pedagogy. Cooperative learning is students working together to accomplish shared goals (Johnson et al., 1991). Students collaboratively engage in activities that are "beneficial to themselves and to all other members of the group. Cooperative learning is the instructional use of small groups so that students work together to maximize their own and each other's learning" (Johnson et al., 1991). Students working in small groups are collaborating, but are only cooperating if

they are trying to accomplish shared goals. The Good, Grouws, and Mason (1990) study examined the relationship between teachers' beliefs about small group instruction and their instructional practice using small groups.

Brody and Hill (1991) and Good, Grouws, and Mason (1990) focused on teachers' perceptions about cooperative learning in mathematics. Both studies were qualitative in design but the Brody and Hill (1991) study used interviews and the Good et al. (1990) study used questionnaires to collect data. It was found that teachers do have specific beliefs about cooperative learning. Brody and Hill (1991) conducted a cooperative learning workshop for 25 K-12 educators. Following the workshop, fifteen educators were interviewed about their beliefs on cooperative learning. Pre-workshop, post-workshop comparisons were not conducted.

A detailed survey instrument was administered in the Good et al. (1990) study to determine the variability of responses concerning cooperative learning definitions and strategies. Descriptive statistics were obtained from the responses. Some of the findings indicated that 39% of the teachers use one of the following all the time: whole-group instruction, but allow individual seatwork for part of the

period; whole-group instruction, but allow small-group work for part of the period; or two or more groups all of the period, but as the teacher helps one group the other students work individually. Approximately 60% of the teachers use small-group instruction less than three days a week and 52% of the teachers surveyed devote less than 15 minutes to small-group work during class time. Since the data collected by Good et al. (1990) was self-reported by teachers, the correlation between their beliefs and actual practice remains to be seen. Studies showing the complex relationships between teacher beliefs about cooperative learning and actual classroom practice qualify for future research.

Brody and Hill (1991) recommend further studies concerning educators' existing beliefs about cooperative learning. They emphasize the need for a "thorough investigation about the congruency of cognitive changes and actual practice through ethnographies of classrooms designated as cooperative learning environments" (p. 41). Future studies need to address the possibility of examining the relationship between teachers' professed beliefs about cooperative (or collaborative) learning in mathematics (particularly collegiate reform calculus) and their instructional

practice. Cooney, Grouws, & Jones (1988) recommend future research in the generalized area of beliefs or perceptions about mathematics teaching. Since collaborative learning is a technique used to teach mathematics, future research on this topic needs to be addressed.

The Harvey et al. (1968), Peterson et al. (1989), Schwartz and Riedesel (1994), and Good et al. (1990) studies were performed at the elementary level whereas the Thompson (1984) study sampled junior high school teachers and the Brody and Hill (1991) study sampled K-12 teachers and administrators. This reflects a need for these types of studies at the secondary or post-secondary level of instruction.

Interviews, questionnaires, and observations were used to gather information while a variety of techniques ranging from qualitative case studies to quantitative methods of correlation, regression, t-tests, and descriptive strategies were used to analyze the data. The Harvey et al. (1968) study was quantitative using t-tests along with descriptive statistics. Although the Peterson et al. (1989) study was qualitative in design, depicting interview and case study approaches, correlations were examined. Studies examining

instructors' perceptions of collaborative learning in relation to their actual instructional practice, their students' perceptions of collaborative learning, and student achievement encompassed a variety of data collection techniques and analyses.

Teachers' Change in Beliefs

As instructors encounter, learn, and incorporate collaborative learning strategies in their classrooms, perceptions of the concept can change during the semester. Collier (1972), Marks (1990), and Thompson (1984) determined that teachers' changes in perceptions of mathematics and mathematics teaching occur due to their own teaching experiences and past learning experiences. As instructors use collaborative learning in their classrooms, their perceptions concerning the nature of collaborative learning can change. This is sometimes influenced by student reactions to the instructional strategy. Identifying these changes in perceptions about collaborative learning could be of interest to the mathematics education community. Also, finding any relationships between instructors' changes in beliefs, students' changes in beliefs, and instructors' actual teaching practice could provide mathematics

instructors with information to help them adapt their teaching to best support meeting the goals of reform calculus.

Collaborative Learning in Other Subject Areas

Mathematics is not the only subject where small group work is used as an instructional strategy. At MSU-Bozeman, many English courses are taught using peer writing groups. English instructors have found that "problematic college writing groups can be good for students" (Tebo-Messina, 1989). Incorporating writing groups in English classes can teach students the many useful applications of writing skills in future careers (Houston, 1990). As in the mathematics classroom, collaboration in the writing classroom "facilitates students' problem-solving skills, diminishes the fear of participating in discussions, and leads to the written expression of more comprehensive ideas" (Houston, 1990).

Science classes from elementary to graduate school utilize small student groups in performing experiments and problem solving in laboratory settings. At MSU-Bozeman, small group work is used in collegiate mathematics classrooms, science labs, and computer science courses, as well as graduate courses in mathematics, science,

and education. "Group learning has several strengths: increasing group members' confidence, increased knowledge through exchange of ideas, increased creativity through shared responsibility, and the opportunity for people to get to know others in work settings" (McElhinney & Murk, 1994). Group learning can be used at all levels of education, including graduate school. Small group work in graduate courses can help prepare students to meet professional career challenges and enrich adult learning which may not be fostered by individual learning alone (McElhinney & Murk, 1994).

Small group learning can also be utilized in social science and humanities courses from elementary to graduate school. Collegiate instructors are using collaborative learning to assist students in learning more effectively (Sheridan et al., 1989). High school social studies instructors have begun to examine the use of small group work as an alternative instructional approach (Bliss, 1989). Bliss notes that more restructuring of current instructional practices, encouragement of reform, and research needs to be addressed before instructors can effectively use small group work in their social studies classrooms (1989). Articles describing ways to implement

small group work in the social sciences are becoming more numerous (Baloche, 1994; Jackson & Prosser, 1985, 1989).

Business and management courses in high school and college are also utilizing small groups to solve real world management problems in the business community (Mello, 1993). There appears to be a need, demand, and use for small group work in many other subject areas besides mathematics and science. Outside of higher education, vocational education classes are using small groups to enable students to "realize greater achievement and greater levels of understanding, have an ability to absorb content that requires higher levels of thinking, and be able to retain what they have learned longer" (Lankard, 1992). In the real world, workplaces are demanding that their employees be able to work cooperatively. Thus, educational institutions from higher education to vocational and from elementary to graduate are utilizing small group work, cooperative learning, and/or collaborative learning as an alternative instructional strategy.

Role of the Systemic Teacher Excellence Preparation Project

The Systemic Teacher Excellence Preparation (STEP) Project is a statewide collaborative designed to bring about "large-scale" improvement in the preparation of mathematics and science teachers in Montana and serve as a national model for rural areas with significant minority populations (STEP, 1993). The STEP Project is a five-year program funded by the National Science Foundation (NSF) which began in 1993. The STEP Project is in the process of creating a statewide interactive network consisting of the five state colleges and universities with teacher preparation programs, six tribal colleges, public and private elementary and secondary schools, statewide teacher associations such as the Montana Council of Teachers of Mathematics (MCTM) and the Montana Science Teachers Association (MSTA), and other existing grant projects such as the Systemic Initiative for Montana Mathematics and Science (SIMMS), the Alliance of States Serving Indians in Science and Technology (ASSIST), and the Six Through Eight Mathematics (STEM) Projects.

One portion of the STEP Project includes a team approach to redesigning approximately fifty university mathematics, science, and education methods courses for pre-service teachers in Montana.

Changes of curricula were planned that would: (1) show how mathematics and science could be integrated; (2) enable students to use manipulatives; (3) engage students in inquiry, discovery, problem solving, and model building; (4) incorporate group work (cooperative or collaborative learning); (5) allow for a variety of learning strategies; (6) present real world applications of mathematics and science; (7) incorporate appropriate uses of technology such as graphing calculators and computers; (8) include a variety of assessment strategies; (9) incorporate various instruction strategies such as lecture, presentations, inquiry, questioning techniques, discovery learning, cooperative (collaborative) learning, presentations, alternative assessment, classroom management, and motivation; and (10) use appropriate strategies to engage female and minority students in the learning of mathematics and science (STEP, 1993).

As a Research Assistant with the STEP Project, this researcher became involved with the implementation phase of the reform calculus textbook developed by the Calculus Consortium based at Harvard University (Hughes-Hallet et al., 1994a). While attending MSU-Bozeman (1993-1996), this researcher assisted the

mathematics department and the STEP Project in implementing collaborative learning in the calculus classroom. This researcher had used collaborative learning in the calculus classroom while instructing at a southern university before coming to MSU-Bozeman.

First semester engineering calculus was required for secondary mathematics education students. Collaborative and cooperative learning are of special interest to the STEP Project. Cooperative learning is similar to collaboration with the inclusion of working toward a common, shared goal (Slavin et al., 1985). Cooperative learning is important to STEP, because the Standards (NCTM, 1989) recommend its use, as does the Mathematical Association of America (MAA), the Mathematical Sciences Education Board (MSEB), and the business, engineering, and science communities. As calculus instructors model collaborative learning techniques in the classroom, the STEP Project anticipates that future secondary mathematics teachers will teach in ways similar to the way they were taught. The STEP Project promotes those instructional techniques relevant to the goals of reform calculus.

CHAPTER 2

METHODS AND PROCEDURES

Introduction

The six calculus instructors for this study were graduate teaching assistants in mathematics: two are master's degree candidates in mathematics, three are doctoral candidates in mathematics, and one is a doctoral candidate in mathematics education. They taught a reform calculus course that utilized collaborative learning techniques. They could have views concerning collaborative learning that differ from the recommended ways collaborative learning is used when teaching reform calculus. The major questions of this study were: how do these calculus instructors perceive collaborative learning and use collaborative learning in their teaching and, what effect do these perceptions and use have on student achievement? The study attempted to determine the separate and collective contributions of: (1) the calculus section effect, (2) students' perceptions of collaborative learning, and (3) students' perceptions of their instructors' views of collaborative learning, in explaining variability in student

mathematical achievement on a comprehensive final examination. Each instructor's actual teaching practice utilizing collaborative learning was also examined and related to instructors' and students' perceptions about collaborative learning.

Mathematics instructors who teach collegiate calculus can have perceptions concerning collaborative learning that affect how they teach. This researcher believed that finding any preconceived views (on the part of the instructor) about collaborative learning in the calculus classroom can assist mathematics instructors in adapting their teaching to the goals of reform calculus. Mathematics educators are interested in finding out, through research, whether the instructor's understanding and use of collaborative learning techniques increases student success in learning calculus.

Prior to teaching the first semester engineering calculus course, each instructor (i.e. graduate teaching assistant) attended a training workshop on the use and implementation of collaborative learning. This workshop took place two days prior to the beginning of the Fall semester, 1995. It was a two-day workshop addressing group structure, dynamics, philosophy, and problems. The workshop agenda is shown in Appendix A. Several experienced first semester

engineering calculus instructors were available to offer advice and suggestions for collaborative teaching strategies.

Conceptual Framework

Mathematics instructors (i.e. graduate teaching assistants) who teach collegiate calculus could have perceptions or beliefs concerning collaborative learning that influence their instructional practice, their students' perceptions about collaborative learning, and the resulting student achievement in calculus. Research indicates that teachers who have particular views about specific mathematics instruction ideas often exhibit these perceptions in the classroom during instructional practice (Brown & Baird, 1993; Kagan, 1992). For example, Thompson (1984) found that there were consistencies between teachers' professed perceptions of mathematics and mathematics teaching and the manner in which they usually presented the content. Identifying instructors' professed perceptions about collaborative learning in the calculus classroom could lead to ways of assisting them in adapting their teaching procedures that support the goals of reform calculus. One of the goals of reform calculus is to have students work together in the classroom (Hughes-

Hallet et al., 1994a). Collaborative learning is a suggested way for students to work together. Reform calculus courses which utilize collaborative learning could have a greater success rate with students than those who do not use collaborative learning. The Tulane Conference used that assumption when they laid the foundation for reform calculus (MAA, 1986).

The conference at Tulane University in January, 1986, prompted a discussion among mathematics educators concerning calculus instruction. Participants charged that "calculus was not being taught in a way befitting a subject that was once the culmination of the secondary mathematics curriculum and the gateway to collegiate science and mathematics" (MAA, 1993, p. vii). They charged that the syllabi for the new calculus classes should contain fewer topics, but have more conceptual depth, both numerically and geometrically. The Calculus Consortium based at Harvard University constructed a reform calculus textbook that incorporated these suggestions (Hughes-Hallet et al., 1994a). Reform calculus textbook authors also changed the example problems, concept explanations, and homework problems to fit the mold that Tulane Conference participants suggested. These textbook changes