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
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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.

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

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

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Bozeman, Montana

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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.

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.
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-
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
accompanied a change in the recommended instruction. Although reform calculus often has different meanings for different mathematics educators involved in the reform effort, there does 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 allowing instructors to facilitate student learning by questioning students and promoting class discussion (Hughes-Hallet et al., 1994b). These ideas for change are generally recommended as suggested changes that can positively affect calculus 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).
Many instructors of reform calculus courses have included small group learning (i.e. collaborative learning) into the weekly class routine upon encouragement of reform calculus textbook authors (Dubinsky & Schwingendorf, 1992; Hughes-Hallet et al., 1994a; Smith & Moore, 1993). This change in calculus instruction can have an effect on student learning. Instructors have certain perceptions of collaborative learning that may or may not be synonymous with the perceptions of reform calculus textbook authors. These instructor perceptions can influence their students to view collaborative learning in a certain way and can affect student achievement in reform calculus.

The National Council of Teachers of Mathematics has encouraged the use of small group work in the K-12 curriculum (1991). Many students are very familiar with using small group work when they enter college. Some students hold perceptions about collaborative learning that can affect their achievement in reform calculus. Identifying student perceptions as well as their instructor's perceptions of collaborative learning could affect student achievement.
Description of Population

Montana State University-Bozeman (MSU-Bozeman) is one of five state universities in the state of Montana (MSU, 1994). It lies at the southern edge of the city of Bozeman, population 30,000, and is set in the heart of Gallatin County which is surrounded by rich farmlands and scenic mountains. It is a land-grant institution created by the Morrill Act of 1862 and formally established on February 16, 1893. Today, MSU-Bozeman offers bachelor’s degrees in 45 fields covering 117 areas, master’s degrees in 38 fields, and doctorate degrees in 15 fields (including mathematics and education). Approximately 75 percent of the 10,800 enrolled students are Montana residents (MSU, 1994). The average student to faculty ratio at MSU-Bozeman is approximately 19.5:1. However, the first semester engineering calculus (Calculus and Analytic Geometry I) average student to faculty ratio is approximately 30:1. Traditionally, students enrolled in first semester engineering calculus seek engineering, mathematics, or science degrees.

One hundred and thirty three students from six sections of first semester engineering calculus (MSU-Bozeman) participated in this study during the Fall semester, 1995. Approximately 40 students
per section were initially enrolled in first semester engineering calculus. Thus, approximately 240 university students were initially participating in this study, as well as the six first semester engineering calculus instructors (i.e. graduate teaching assistants). Due to student withdrawals during the semester, between 25 and 40 students per section completed the course.

Student placement in first semester engineering calculus was based on performance on the MSU-Bozeman Mathematics Department’s placement examination, Scholastic Aptitude Test (SAT), or American College Test (ACT). Outstanding prior mathematics performance was also considered when placing students in first semester engineering calculus.

**Sampling Procedures**

MSU-Bozeman was chosen because: (1) engineering calculus is taught using graduate students as instructors, (2) a reform calculus textbook is used, and (3) the instructors are encouraged to use collaborative learning in their teaching on the MSU-Bozeman campus. Six graduate teaching assistant instructors were chosen for this study. Class size for each instructor was between 25 and 40
students. Eight sections of first semester engineering calculus were taught during the Fall semester, 1995. However, two sections were dismissed from this study because the instructors had prior experience in teaching first semester engineering calculus using collaborative learning. Instructors were mathematics graduate teaching assistants in first semester engineering calculus who had not previously taught the course at MSU-Bozeman using the reform calculus textbook, *Calculus*, written by Hughes-Hallet et al. (1994a).

The research design for this study did not include a formal sampling procedure. All graduate teaching assistants teaching first semester engineering calculus during the Fall semester, 1995, were involved in this study. The prerequisite for graduate teaching assistants participating in this study was that they had not previously taught first semester engineering calculus at MSU-Bozeman using the Hughes-Hallet et al. textbook (1994a). Also, due to the large number of first semester engineering calculus sections available (eight), randomization of student enrollments in each section was inherent in MSU-Bozeman’s scheduling process.
Description of Treatments

Teacher Training and Implementation

A two-day collaborative learning workshop prior to the Fall semester, 1995, was required of all instructors involved in the instruction of first semester engineering calculus. Two days were considered sufficient to introduce the graduate teaching assistants to collaborative learning.

The main purpose of workshops (in general) is to learn how to do something better or to understand something better. Participants adopt the role of learners. Resource persons have high expertise and behave as instructors. The workshop may involve the learning of skills and thus involve much practice (Sork, 1984, p. 4).

The purpose of the collaborative learning workshop was to educate and train the graduate teaching assistants in the use of collaborative learning in first semester engineering calculus. The workshop schedule used in this study is included in Appendix A and follows the workshop planning guidelines as set in Planning, conducting, and evaluating workshops (Davis, 1974). Collaborative learning training encompassed a variety of techniques. They included: (1) instructors working in small groups, actively involved in mathematical problem solving and discussion, (2) instructors working on textbook
homework problems in order to familiarize themselves with the small group problems, and (3) instructors experiencing collaborative learning skills as students in order to more effectively use collaborative learning as instructors. The collaborative learning consultant (this researcher) discussed group structuring, the dynamics of group learning, and the philosophy of group learning. Collaborative learning techniques were discussed in the workshop. Experienced first semester engineering calculus instructors (graduate teaching assistants, part-time faculty, and full-time faculty) who had used collaborative learning successfully shared comments on collaborative learning strategies that they had used. As a result, instructors had the opportunity to: (1) become familiar with collaborative learning, (2) learn how to use collaborative learning successfully in the classroom, and (3) be prepared to use collaborative learning activities to instruct first semester engineering calculus. Alternative assessments, use of technology (mostly graphing calculators), and classroom management techniques are topics that were also addressed in relation to collaborative learning.

The workshop took place two days prior to the beginning of the Fall semester, 1995. According to Sork (1984), workshop
participants can immediately apply the results of their training in their classrooms. This is an advantage of the short, intensive workshop. Another advantage of the collaborative learning workshop was the small number of participants. Working with only six participants demonstrated the group dynamics philosophy and allowed for easy workshop management (Sork, 1984). Inviting experienced instructors (graduate teaching assistants, part-time faculty, and full-time faculty) to share ideas on how to use collaborative learning in the first semester engineering calculus course was helpful in generating informative discussions between the workshop participants.

Collaborative Learning

The amount of collaborative learning taking place in each first semester engineering calculus classroom depended on the instructor. The first semester engineering calculus course supervisor and workshop facilitators encouraged approximately two days (100 minutes) of in-class group work per week (first semester engineering calculus meets for 50 minutes each day, five days a week). The pilot study showed that instructors vary in the amount of time they spend
on collaborative learning tasks during class. Collaborative learning observation checklists (Appendix B), instructor questionnaires (Appendix C), student questionnaires (Appendix D), instructor interviews (Appendix E), student interviews (Appendix F), and weekly collaborative learning logs (Appendix G) were used to collect data on the average amount of in-class time spent on collaborative learning activities per week.

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 activities included: (1) small groups working on homework problems, extended or complex problems, or group quizzes, and (2) small groups engaging in discussions concerning textbook concepts.

Methods of Data Collection

The data collection instruments were piloted in first semester engineering calculus classes during either the Fall semester, 1994, or the Spring semester, 1995, at MSU-Bozeman. The instruments were modified after the pilot studies to reflect changes recommended by
three mathematics and science educators. They are contained in Appendices B - F.

Modified instruments were given to three mathematics and science educators at MSU-Bozeman. These educators examined the instruments for validity. Changes were made to each instrument to accommodate their requests and then re-validated by the three educators. Under the supervision of a statistician in the mathematics department and a statistics consultant in the Office of Applied Research Services at MSU-Bozeman, reliability was addressed on instructor and student questionnaire instruments during the Summer semester, 1995.

The student and instructor questionnaires were piloted in first semester engineering calculus during the Summer semester, 1995. Test-retest reliability (Pearson r product moment correlation coefficient) and internal consistency (Cronbach's alpha) coefficients were calculated on the piloted instruments. A consultant in the Office of Applied Research Services assisted this researcher in calculating these coefficients. The internal consistency coefficient for the instructor questionnaire was 0.97 and the result of the Pearson r reliability test was 1.00 because there were just two cases. A t-test
of paired means was also performed and results showed an alpha of 0.58. Results indicated that there was not a significant difference between the two questionnaire means for each case (n=2).

Reliability and internal consistency coefficients were also determined for the student questionnaire. This instrument measured two subsets of information: (1) students' perceptions of collaborative learning and (2) students' perceptions of their instructors' views of collaborative learning. Due to the small number of enrolled students, sixteen cases were analyzed. Results for the Cronbach's alpha coefficient (internal consistency) showed 0.90 for subset 1 and 0.78 for subset 2. Three questions were omitted from the analysis because of internal inconsistency. These three questions were removed from the questionnaire for the Fall semester, 1995, or revised to remove vague expressions in each item. Pearson r product moment correlation coefficients showed 0.75 for subset 1 and 0.62 for subset 2. The same three questions were also omitted from this analysis because of internal inconsistencies previously found. The final questionnaire instruments are found in Appendices C and D.

The instructor interview was piloted twice during the Summer semester, 1995. Modifications were made prior to its use in the Fall
semester, 1995. The collaborative learning checklist was piloted twice during the Summer semester, 1995, in one first semester engineering calculus class. This class used small group work on a daily basis. This instrument was also revised prior to its use in the Fall semester, 1995. Two mathematics and science educators at MSU-Bozeman validated this effort.

Some of the collected data was in descriptive form resembling qualitative data. Despite the quantitative nature of this study, this researcher exhibited triangulation procedures to provide cross-data validity checks of the descriptive data (Patton, 1990, p. 188). The data collected on the observation checklists and weekly collaborative learning logs triangulated instructor and student interview data as well as instructor and student questionnaire data (Patton, 1990).

Collaborative Learning Observation Checklist

The collaborative learning observation checklist has been constructed and modified following feedback from six first semester engineering calculus instructors during the Fall semester, 1994. The checklist was used approximately twenty times on seven first semester engineering calculus instructors during the Fall semester,
1994. Modifications were made during the semester. Because of the recommendations of Babbie (1995) and Oppenheim (1966), these modifications lead to the construction of a Likert-type instrument for use in first semester engineering calculus during the Summer semester, 1995. The collaborative learning checklist was piloted twice during the Summer semester, 1995, in one first semester engineering calculus class. This class used small group work on a daily basis. This instrument was then revised prior to its use in the Fall semester, 1995. Two mathematics and science educators at MSU-Bozeman validated this effort. The instrument was used to collect data on actual teaching practice of the first semester engineering calculus instructors during the Fall semester, 1995. Instructors were notified of the observations so that group work could be observed. This researcher randomized the observation patterns (to the best of her ability) once instructors set weekly schedules for lecture and group work.

The collaborative learning observation checklist is shown in Appendix B. All instructors were observed nine times each during the course of the semester. There were 15 weeks in the semester and
observations were performed during the second through fourteenth weeks. The results of the observations were analyzed qualitatively.

Instructor Collaborative Learning Questionnaire

During the Spring semester, 1995, thirteen first and second semester engineering calculus instructors (graduate teaching assistants, part-time faculty, and full-time faculty) at MSU-Bozeman were interviewed about their perceptions of the textbook (Hughes-Hallet et al., 1994a), group work, and technology. Instructors were also asked to explain their weekly classroom routines, use of technology and group work, and their group work management plans. An instructor questionnaire was constructed from the comments stated by the instructors. Oppenheim (1966) states that early questionnaire design is often exploratory and may involve lengthy interviews. Following this stage of the questionnaire development, the researcher then constructed a questionnaire taking into account the comments from the interview (Oppenheim, 1966). Once the questionnaire had been created, Babbie (1995) and Oppenheim (1966) encouraged piloting the instrument to remove any errors that may have occurred during its construction. The
instructor questionnaire was piloted during the Summer semester, 1995, in two first semester engineering calculus classes. Test-retest reliability coefficients (Pearson r product moment correlation), a t-test of paired means, and internal consistency coefficients (Cronbach's alpha) were obtained during the pilot study, as previously mentioned. The questionnaire was administered at two different times to two first semester engineering calculus instructors and the correlation coefficients between the two sets of scores were calculated. A minimum of two weeks passed between test and retest to minimize the effects of memory and other variables (Shaw & Wright, 1967).

The collaborative learning questionnaire for instructors obtained data concerning the instructors' perceptions of collaborative learning in the reform calculus classes. The instrument (shown in Appendix C) was administered to the instructors three times during the course of the semester: (1) the first time was just prior to the collaborative learning workshop, (2) the second time was around midterm of the semester, and (3) the final time was during the week prior to finals (end-of-term). Friedman's test was conducted on the
three sets of collected data to determine if instructors’ perceptions of collaborative learning changed over time.

**Student Collaborative Learning Questionnaire**

An open-ended instrument was designed and used to collect data on first semester engineering calculus students’ perceptions of the reform calculus textbook (Hughes-Hallet et al., 1994a), group work, and technology during the Fall semester, 1994, at MSU-Bozeman. Upon analysis of the comments, this researcher created a Likert-type questionnaire that was piloted in fourteen first and second semester engineering calculus sections during the Spring semester, 1995. Recommendations by Babbie (1995) and Oppenheim (1966) resulted in similar steps being taken as in the construction of the instructor collaborative learning questionnaire. Modifications were made on the instrument used to collect students’ perceptions of collaborative learning and students' perceptions of their instructors' perceptions of collaborative learning. This revised instrument was examined by three mathematics and science educators at MSU-Bozeman prior to the pilot study which was conducted in two first
semester engineering calculus sections during the Summer semester, 1995.

Test-retest reliability (Pearson r product moment correlation coefficient) and internal consistency (Cronbach's alpha) coefficients were calculated on the student questionnaire instrument as previously mentioned. The questionnaire was administered at two different times to two sections of first semester engineering calculus students. The correlation coefficients between the two sets of scores were calculated. A minimum of two weeks passed between test and retest to minimize the effects of memory and other variables (Shaw & Wright, 1967). Three mathematics and science educators validated this instrument prior to its use in this study during the Fall semester, 1995.

Following the Summer semester, 1995, the modified instrument was administered to the students three times during the course of the Fall semester, 1995. The collaborative learning questionnaire for students obtained data concerning each student's perceptions of collaborative learning and each student's perceptions of his/her instructor's perceptions of collaborative learning in the reform calculus classes. The instrument was administered to the
students three times during the course of the semester: (1) the first time was during the first week of the Fall semester, 1995, (2) the second time was around midterm of the semester, and (3) the final time was during the week prior to finals (end-of-term). End-of-term results on this instrument (shown in Appendix D) served as the independent variable of students' perceptions of collaborative learning. The change in students' perceptions of collaborative learning was also examined. Friedman's test was conducted on the three sets of collected data to determine students' change in perceptions.

Instructor Interview

The instrument used for instructor interviews during the Spring semester, 1995, was modified for use during this study. The data collected with the instrument addressed the issues of instructor perceptions of collaborative learning in a reform calculus class and indicated instructor perceptions concerning actual teaching practice. Appendix E shows the modified instructor interview instrument. During the Summer semester, 1995, the instructor interview instrument was piloted at MSU-Bozeman on two first semester
engineering calculus instructors and modified prior to its use during the Fall semester, 1995. This instrument was administered once (at midterm) during the Fall semester, 1995.

The instructor interview instrument collected descriptive data about each of the first semester engineering calculus sections and served to triangulate responses to open-ended questions with the instructor collaborative learning questionnaire.

Student Interview

The instrument used for student interviews during the Fall semester, 1995, was created and modified during the Summer semester, 1995. The data collected with the instrument addressed the issues of students' perceptions of collaborative learning, students' perceptions of their instructors' views of collaborative learning, and indicated student perceptions concerning actual teaching practice in the reform calculus class. Appendix F shows the student interview instrument.

The student interview instrument collected descriptive data about each of the first semester engineering calculus sections and
served to triangulate responses to open-ended questions with the student collaborative learning questionnaire.

**Weekly Collaborative Learning Log**

The weekly collaborative learning log (Appendix G) collected descriptive data about each of the first semester engineering calculus sections. They were constructed and modified during the Summer semester, 1995. The weekly logs were completed by the six calculus instructors during the Fall semester, 1995. The logs indicated the amount of time instructors spent lecturing, utilizing collaborative learning, and performing other tasks.

**Student Comprehensive Final Examination**

The student comprehensive final examination (Appendix H) was required of all first semester engineering calculus students before an end-of-semester analysis of grades could take place. For the purposes of this study, the numerical score of the student comprehensive final examination served as the dependent variable of student mathematical achievement in first semester engineering calculus.
During the Fall semester, 1994, a two-hour comprehensive final examination was given to approximately 250 first semester engineering calculus students at MSU-Bozeman. The test reflected the concepts discussed in a first semester engineering reform calculus course using the textbook by Hughes-Hallet et al. (1994a). A similar, but not identical, instrument was used during the Spring semester, 1995, to test approximately 200 first semester engineering calculus students on concepts learned during the entire semester. Construction of the first semester engineering calculus final examination for the Fall semester, 1995, was modeled after the two previous final examinations from the Fall semester, 1994, and the Spring semester, 1995. Although final examination reliability and validity may be in question, formally establishing these can be diminished since each examination is constructed to test the concepts taught during the course of the semester. Gronlund and Linn (1990) explain that lower reliability can be tolerated if there exists other means of confirming the decision to use the data. The fact that similar first semester engineering calculus final examinations have been used for two consecutive semesters at MSU-Bozeman suggest that similar or equivalent-form instruments should be reliable and
valid. The supervisor and course instructors of the Fall semester, 1995 first semester engineering calculus courses examined the comprehensive final examination to ensure proper alignment between content taught and content tested.

The data collected on the student comprehensive final examination (administered only once during the week of finals during the Fall semester, 1995) is the dependent variable information needed for the study.

Research Design

The type of correlational design used in this study is the “one-group repeated trials” design (Kerlinger, 1973, p. 362). As the name indicates, one group (first semester engineering calculus students and their instructors) was measured at different times during the semester to examine the effects of the treatments. The study followed this design and can be related to a “one-group, before-after” design (Kerlinger, 1973, p. 363). However, instruments were administered more than twice during the course of the semester, except for the first semester engineering calculus comprehensive final examination.
The design does have its drawbacks. The regression effect could have affected the design because over time, instrument scores may tend to lean toward mediocrity. Also, history and maturation could have been a problem with the design (Kerlinger, 1973). Specific events (e.g. student or instructor personal dilemmas, student and instructor personality differences, etc.) could have occurred between measurements that might have affected the collected data. Also, the subjects in this study would likely change or mature during the course of the semester. Including a control group is often the best way to combat such difficulties. However, since the MSU-Bozeman first semester engineering calculus environment did not lend itself to the use of control groups, the study examined one group of subjects from six first semester engineering calculus sections and correlated several independent variables related to the use of collaborative learning with the dependent variable of student achievement on a first semester engineering calculus comprehensive final examination.

Mortality was not expected to be a problem. However, one initial instructor withdrew from the study nine days after the start of the semester. Students were most likely not affected by this
change because it was early in the semester and drop/add changes had not been finalized at that time. Student subject mortality did occur because approximately 240 initial subjects were enrolled in the first semester engineering course and 133 students completed the study. Many students dropped the course during the semester or were not included in the study because they failed to complete all three questionnaires.

Test sensitization was not a problem since the student subjects were surveyed three times during the semester (Kerlinger, 1973). The questionnaires were administered with an elapsed time of seven weeks between questionnaires. Instructor subject data was collected: (1) three times on questionnaires, (2) during an interview, and (3) during nine weekly collaborative learning observations. There was no evidence that test sensitization was a problem in this situation.

The instructors selected for this study were graduate teaching assistants who had not previously taught first semester engineering calculus (using the Hughes-Hallet et al., 1994a, textbook) prior to the Fall semester, 1995. The calculus students and registrar's office at
MSU-Bozeman selected the student population in the first semester engineering calculus sections during the Fall semester, 1995.

Analysis of Data

The independent variables to be used in this study were: (1) the calculus section effect, (2) students' perceptions of collaborative learning, and (3) students' perceptions of their instructors' views of collaborative learning. The dependent variable to be used in this study was the first semester engineering calculus students' comprehensive final examination scores. Instructors' actual teaching practice utilizing collaborative learning was also examined and related to instructors' and students' perceptions. Gender and ethnicity were noted in relationship to the dependent and independent variables (Ott, 1988). Gender and ethnicity were not major research components in this study.

The techniques of analysis of variance, multiple regression, Pearson r correlation, and two nonparametric tests (Spearman's Rho and the Friedman test) were used to analyze the data. Students' achievement scores on the comprehensive final examination served as the post-test for this study.
SAS, MINITAB, and Excel were recommended by MSU-Bozeman's statisticians and used to analyze the data.

**One-Way Analysis of Variance**

The ANOVA test was used to determine if there were statistical differences between the six sections on the students' final comprehensive examinations. The ANOVA test was also used to determine if there were statistical differences between the six sections on seven student questionnaire items that addressed students' perceptions.

**Multiple Linear Regression**

The multiple linear regression model was used to find out how the independent variables (calculus section effect, students' perceptions of collaborative learning, and students' perceptions of their instructors' views of collaborative learning) collectively contributed to the variability of the dependent variable (students' final examination scores). Statistical significance was determined by examining the calculated p-values. The best model was determined
by examining the amount of final examination score variability explained by the independent variables.

**Pearson r Correlation Test**

Pearson r coefficients were calculated to determine the separate contributions 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, to the dependent variable (student achievement on a comprehensive final examination in reform calculus).

**Friedman's Two-Way ANOVA by Ranks Test**

The nonparametric Friedman test was performed on the data collected from the collaborative learning questionnaire instruments. This test determined if there were changes over time in students' and instructors' perceptions of collaborative learning. This technique was used to determine differences in mean scores within the groupings of: (1) the instructors' perceptions of collaborative learning and (2) the students' perceptions of collaborative learning.
Spearman's Rho Rank Correlation

The nonparametric Spearman's Rho Rank Correlation test was performed to examine correlations between students' mean responses on the student questionnaire and their respective instructor responses on the instructor questionnaire.

Choice of Alpha Level

A level of significance commonly used in educational research is $\alpha = 0.05$ (Wiersma, 1986, p. 338; Borg & Gall, 1989, p. 351; Best & Kahn, 1989, p. 273; Ferguson & Takane, 1989, p. 182). Researchers choose the level of significance in order to reduce the possibility of Type I or Type II error. A Type I error occurs when a true null hypothesis is incorrectly rejected and a Type II error occurs when researchers fail to reject a false null hypothesis. Both errors are of interest to this researcher, but because this study is dealing with attitudes concerning collaborative learning, committing a Type II error is of greater consequence. A Type II error could result in failure to advocate collaborative learning when, in fact, a relationship exists between students' high marks on a first semester engineering calculus comprehensive final examination and positive attitudes of
students and instructors towards collaborative learning. Thus, \( \alpha = 0.05 \) was chosen as the level of significance for analyses in this study in order to reduce a possible Type II error. P-values were also calculated for the above-mentioned statistical tests.

**Statistical Hypotheses**

The hypotheses derived from the research questions were as follows:

1. There is no statistically significant relationship between the dependent variable (student achievement on a comprehensive final examination) and the *collective* contribution of the independent variables (the calculus section effect, students' perceptions of collaborative learning, and students' perceptions of their instructors' views of collaborative learning).

2. There is no statistically significant relationship between the dependent variable (student achievement on a comprehensive final examination) and the *separate* contribution of the independent variables (the calculus section effect, students' perceptions of collaborative learning,
and students’ perceptions of their instructors’ views of collaborative learning).

3. There is no statistically significant change in instructors’ perceptions of collaborative learning throughout the semester in the reform calculus course.

4. There is no statistically significant change in students’ perceptions of collaborative learning throughout the semester in the reform calculus course.

5. There is no statistically significant difference (for each instructor) between students’ perceptions of their instructors’ views of collaborative learning and their instructors’ stated perceptions.

Limitations and Delimitations

The limitations of the study were as follows:

1. The study was limited to six graduate teaching assistants from MSU-Bozeman teaching the first semester engineering calculus sections.

2. The student subjects were limited to 133 first semester engineering calculus students.
3. Control over instructor differences was limited to the effects of a collaborative learning training workshop and researcher monitoring, observing, and intervention.

4. All of the first semester engineering calculus sections were limited to classrooms of students which were student-selected and selected by MSU-Bozeman's registrar's office.

5. Collaborative learning observation checklists involved researcher evaluation which is subject to researcher error.

6. The first semester engineering calculus comprehensive final examination was not formally tested for validity and reliability and is subject to instructor error.

7. This researcher was a proponent of collaborative learning and a calculus instructor who used collaborative learning in the classroom.

The delimitations of the study were as follows:

1. The population of the study involved students and instructors in first semester engineering calculus sections at MSU-Bozeman during the Fall semester, 1995.

2. The period of study was one full semester.
CHAPTER 3

ANALYSES OF DATA

Introduction

A profile has been prepared for each instructor involved in this study and the students in their respective classes (first semester engineering calculus) during the Fall semester, 1995. The profiles were prepared in order to create an accurate picture of the calculus graduate teaching assistant. Pseudonyms were used in place of the assistants' actual names and accurately reflect the teaching assistants' gender. Instructor names alphabetically correspond with the amount of time collaborative learning and lecture were used. Al instructed using a combination of least lecture and most collaborative learning (as compared to the other instructors). Al was followed by Ben, Clyde, Dan, Ellen, and Fran.

The instructor profiles section is followed by the Statistical Analyses section. This section contains the quantitative results. All five null hypotheses were tested at the $\alpha = 0.05$ level of significance.
The Qualitative Analyses section contains findings corresponding to Research Questions 3 - 7. A summary of qualitative findings is included in this section.

Graduate Teaching Assistant Profiles

A profile for each calculus graduate teaching assistant and his/her respective class of students has been created as background for understanding their perceptions of collaborative learning and the instructors’ actual teaching practices. Interview, weekly log, and observation data were used to construct an accurate profile for each instructor. Tables 1 - 4 in Appendix J contain information summarizing and comparing demographic, log, and observation data of the six calculus sections. The individual profiles follow below.

Al

Al was a second year doctoral student in mathematics education at MSU-Bozeman. He planned to resume college or high school teaching in his country (in South America) after obtaining his degree. Al enjoyed teaching and had experience instructing students in mathematics. Al stated that he planned to write his dissertation
on the integrated approach to calculus and wanted "first-hand experience about Harvard calculus teaching and how it works in practice."

Al had never used collaborative learning when teaching mathematics, but had taken chemistry classes where small group work was done in a laboratory setting. Al commented that "it hasn’t been an enormous surprise, but a happy surprise to see courses that one would not call labs where collaborative learning is starting to be used." He saw himself as a proponent of collaborative learning.

Al’s early morning class contained 34 students. A summary of the characteristics of the participating students by gender, ethnicity, class, and major is in Table 1 in Appendix J. Fifteen students (thirteen males and two females), approximately 44% of Al’s class, participated in the study. The participating students completed all three questionnaires and the comprehensive final examination. Al’s class had the smallest percentage of student involvement in the study. All other classes had better than 60% student participation. Of the nineteen students not participating in the study: (1) all failed to complete all three student questionnaires, (2) four were female, (3) six received “B” grades on the final examination, and (4) seven
received "F" grades on the final examination. Of Al’s students participating in the study: (1) nine were freshmen, (2) four were seniors, and (3) two were sophomores. Also, ten of the students were engineering majors while there was one mathematics major and two biology majors. Al’s class had all Caucasian student participants.

Al had a very structured classroom routine. He lectured on Mondays, Wednesdays, and Fridays and facilitated small group work on Tuesdays and Thursdays. On some calculus topics, Al gave short lectures. During weeks with these types of calculus topics, the weekly structure was two days of lecture and three days of small group work. He believed that there should be a balance between lecture and small group work. In Table 2 (Appendix J) one can see the breakdown of total class time for each instructor. Al’s class utilized collaborative learning 31% of the total class time. He used small group work more than any other instructor. He lectured 51% of the time. He lectured less than any other instructor. This information was gathered from the weekly collaborative learning log (Appendix G).
Al took the advice of the course supervisor and formed small groups on the basis of the kind of graphing calculator used. The only other consideration in forming small groups was size. All groups were of size three or four except for one group of two members. Groups of five members were considered too large. When asked about gender equity issues he responded: "I'm color blind but also gender blind in a sense that I make no difference whatsoever."

When students were working in small groups, they were instructed to sit in circles. All observations took place on Thursdays. Information in Table 3 (Appendix J) shows Al's weekly observation schedule. The number of students attending class on observed group days ranged from 26 to 38 students with an average number of 31 students present. Al's students were involved in small group work an average of 35 minutes during the fifty minute class period. Al had the greatest amount of small group work, but the sessions were usually shorter than other instructors. Al usually introduced and discussed group work assignments for approximately 10 minutes before allowing the students to work in groups. Information in Table 4 (Appendix J) indicates the observation summary for Al.
Data from the nine collaborative learning observation checklists (Appendix B) indicated that during the first few weeks of the semester, Al did not grade group work, but he said that he soon "realized [the students] needed more structure." Al designed a cover sheet that was attached to student group work assignments. The cover sheet provided Al with information concerning student roles (leader, devil's advocate, checker, etc.) which the groups' members shared from week to week. This is a technique used in cooperative learning (Davidson, 1990). On Fridays, Al collected individual homework assignments and on Mondays he collected the small group assignments. Al assigned approximately ten problems for small group work. He assigned the largest number of small group problems of any instructor. Al says:

It's a lot of work. I don't expect them to finish their group work in the two hours. That's not realistic. I tell them that in my opinion one of the good things about collaborative learning is that it fosters collaborative learning outside of the classroom. So, several groups are getting together on the weekends and doing the write-ups.

Since small group work was on Tuesdays and Thursdays, students sometimes worked on homework problems (due on Fridays) at the end of the allotted time for small group work. It is interesting to note that Al had indicated at the beginning of the semester that he
would utilize small group work for approximately 50 minutes per week. Upon final analysis, Al utilized small group work for approximately 80 minutes per week.

During small group time Al’s students always had a small group assignment to complete. Problems were chosen from the textbook, but occasionally, Al added a problem from another source. Al always gave objectives and directions for small group work, either written on the chalkboard or verbally. He always gave an introduction to the small group assignment where he usually pointed out common mistakes often made by students when working the problems. Half of the observed time Al provided closure when doing small group work. Group problems never focused only on a single concept; rather, they included many concepts from a particular section of the textbook.

During small group work Al’s students generally sat in tight circles and were performing their tasks. Even though students shared ideas with one another, they usually did not actively collaborate or cooperate when working group problems. Since there were approximately ten assigned problems for students to complete during group work, students divided the workload within the groups.
They seldom cooperated on the same group problem, but they did share problem solutions with one another.

Students were almost never off task, but occasionally were unmotivated. Some groups had members that explained concepts to the whole group, while other groups did not utilize this strategy. The latter groups seemed to break into pairs rather than work as a whole unit. During the third observation of Al’s class this researcher noted:

Students seem tired and not motivated. They work more as individuals or couples. There is very little whole group talk in groups of four or five.

During the ninth observation this researcher noted:

Four groups are sharing and discussing a lot as whole groups. Four groups talk some but not near as much as the other groups. One group broke up and left early. Another group of four split into two groups of two students.

Students attending the classes were almost never late nor did they leave early. However, absenteeism was common. During small group work a student would often work alone because the other members of his/her group were not present. The likely reason for poor attendance in this class is that it started at 8:00 a.m. However, students were almost always writing and recording ideas as they worked in small groups.
When not answering student questions, Al moved from group to group, observing the students at work. He was always available for assistance and usually met with every group before the end of the period. There were generally the same number of questions from individuals as questions from groups. Al gave direct answers to aid students with questions. During three of the nine observations Al answered student questions by writing strategies and partial solutions on students’ papers. He almost never asked a group if any member knew the answer to a question before he had addressed the entire group. Al’s pattern of answering questions varied. Sometimes he responded to a question by addressing the whole group, and at other times he addressed just one or a few students in the group. Even though Al encouraged collaborative learning, he usually did little to reinforce positive group work behaviors in the classroom. Al answered few student questions with questions during group work, but instead he assisted the groups by giving more direct responses. He provided a large amount of help to students when questions arose. Common responses to student questions were generally: “All you have to do is...” or “Then you need to...” Al was a very directive instructor as was shown in his organization of class routine and
lecture, and in his responses to student questions. Al's positive responses to student work were generally: "Very good!" "Nice!" or "OK." Students asked an average of eleven questions during observed small group time. During week four, when permanent groups were formed, students only asked three questions during the period. Generally, students asked Al more than eight questions during a small group session.

Three Caucasian students from Al's calculus class were interviewed about small group work: (1) a senior male (Student 1) majoring in microbiology, (2) a sophomore male (Student 2) majoring in mechanical engineering, and (3) a freshman male (Student 3) majoring in civil engineering. All interviewees believed that Al selected and structured the small groups fairly. However, Students 2 and 3 recommended that Al consider ability level when forming small groups. Student 3 had taken calculus in high school where he experienced small group learning. He recommended that Al "put [students who had previously taken calculus] in a group because they're going to move a little quicker than the rest of the group." Student 2 recommended that Al "look at the grades a little bit and see if [he] could space out the grades a little bit so that [in each group
there are] some people who know what they’re doing and some
people who’re having a little bit of trouble.”

Students 1 and 2 had little previous experience with
collaborative learning. Both students believed there were adequate
amounts of time devoted to lecture and to collaborative learning.
Student 3 commented:

For me I really don’t need the lecture - I’ve already been
through it and I just kind of go to class so I don’t get docked
for the group work because that’s part of my grade. So, I
usually go to class for that reason. I’d like more group work,
but for the other people in my group they would probably
want more lecture so they could understand the concepts
better. I’d like more group work because I [sometimes] have a
tough time understanding our instructor.

All three students interviewed believed Al enjoyed teaching calculus.
Students 1 and 2 believed Al was comfortable facilitating small
group work. Student 3 said: “At times I think he’s a little nervous
about it [facilitating small group work]. He gets a little nervous or
flustered at times. I don’t think he’s used to working in little
separate groups all at different paces.”

Ben

Ben was a first semester graduate student in the Master’s
degree program in mathematics at MSU-Bozeman. He planned to
continue his studies to obtain a doctorate degree in mathematics. Ben enjoyed teaching but admitted that his main reason for teaching was to earn money while being a graduate student. He planned to continue teaching mathematics and performing research after he achieved his doctoral degree.

Ben had some experience with collaborative learning during his undergraduate years at MSU-Bozeman. He minored in Speech/Communications and took several courses that incorporated small group work. He also experienced collaborative learning as an undergraduate student in an English course.

Ben’s afternoon class contained 25 students. A summary of the characteristics of the participating students by gender, ethnicity, class, and major is in Table I in Appendix J. Twenty students (seventeen males and three females), 80% of Ben’s class, participated in the study. The other five male students were not included in the study because they failed to complete all three student questionnaires. Of the twenty participating students: (1) seventeen were freshmen, (2) ten were engineering majors, (3) four were science majors, and (4) five were general studies majors.
Small group sizes were three or four students. Ben was sensitive to the types of graphing calculators students used, which closely correlated with their chosen major. Females and minorities were not given any special considerations in his class. By coincidence, one group of Texas Instrument calculator users contained two females and one male; all three students were considering degrees in mathematics. Ben did not want group sizes larger than four, because he felt that "was just too many." By midterm all groups except one consisted of three members. Ben indicated that he thought groups of three might be the optimal size but:

when you have so many groups of three; it becomes unmanageable for me to visit everybody. Four is not out of hand at all but when you go from three to four [students] you have to have the right mix of people.

Ben actively lectured (questioning students and promoting class discussion) to his class 57% of the total class time while he utilized collaborative learning 24% of the time. This information was gathered from the weekly collaborative learning log (Appendix G). At the beginning of the semester, Ben predicted that he would use collaborative learning for approximately 75 minutes per week, which he accomplished.
Ben felt that he covered the calculus material faster than the stated syllabus, because “I think it’s worth letting them sit down, take the [practice] examination, and realize what they don’t know and then have a few days to correct and adjust it.” Student practice examinations and reviewing for tests encompassed 13% of class time. Information in Table 2 (Appendix J) shows how Ben’s class compared to the other five classes in breakdown of total class time.

Evaluation of student work varied from instructor to instructor. Ben commented: “as far as what I grade, it’s hugely subjective. I’ve seen a student’s work through the whole semester and I’m ready to assign a homework grade at the end of the semester.” He assigned and collected more homework at the beginning of the semester to “get them started on the right foot.” He indicated to his students that when he assigns homework, “it’s their job to do it.” Ben commented that his class is relatively unstructured. He did not use quizzes and only used student presentations once at the beginning of the semester. “Whatever I think I need to do one week, I’ll do it.” Ben never asked students to hand in written work completed within the groups. He assigned homework, collected it from time to time, and had the small groups either discuss concepts or homework problems
during group work. At the beginning of the semester, Ben used overheads to show satisfactory and unsatisfactory examples of written homework problems. Students modeled the suggested format when explaining homework problems. He also wrote solutions to problems on the board in a “verbose” manner to show students how to be “a little more explicit.”

Information in Table 3 (Appendix J) indicates the weekly observations for Ben’s calculus class. Ben began the semester by utilizing small group work several times in a given week. On any given day of the week, Ben might have his students engage in a collaborative learning endeavor. During midterm, Ben said:

On average I started out a lot heavier [using group work] at the beginning of the semester. I’d like to say that on average I do it two days a week but that would be one full day plus maybe 15 minutes at the end of a few class periods that might add up to a whole.

From the nine collaborative learning observation checklists (Appendix B), it was observed that Ben tended to have the students work in small groups on Wednesdays and Thursdays. However, one observation was performed on a Tuesday and another on a Friday. Students engaged in discussing homework problems during small group work more than 50% of the observed time. Toward the end of
the semester, Ben asked the students to participate in small group work to discuss "large-scale" concepts rather than specific homework problems. Groups discussed concepts 50% of the time, whether working on homework or discussing ideas. Ben always explained group work objectives and directions on the chalkboard or verbally. Introductions and closing remarks were each made 50% of the time. During one session, small group work was used for a test review. The average time for student group work was 41 minutes with a range between 15 and 50 minutes of group work time. An average of 21 students participated in group work but it was observed that as few as seven and as many as 25 (the whole class) would attend on group work day. Data in Table 4 (Appendix J) shows a summary of the observations performed during the Fall semester, 1995, calculus course.

Throughout the semester, students seldom arrived late or left class early. Students almost never worked alone. Ben prepared the students for small group work by providing some form of introduction and then remarked "talk to your group now" or "get into circles." Ben often mini-lectured to groups when all group members had difficulty understanding a concept. On three occasions, Ben
spent over fifteen minutes with a group discussing a misunderstood concept. Occasionally, Ben encouraged students to work as a group first to discuss the problems. He almost always answered student questions with questions to help a group, but did give direct responses when appropriate.

Ben made eye contact with his students and encouraged productive behavior as he moved from group to group. Eye contact was a positive characteristic of Ben’s “active lecturer” and small group facilitator roles. He almost always visited each group at least once during the period. As Ben observed and assisted with questions he responded with “nice” or “OK.” Students asked anywhere from one to ten questions (either individual or group) during the course of a period. The average number of questions asked was five. When students were absent from class, Ben asked: “Where are your other group members?” He verbally encouraged participation and attendance at the beginning of the semester.

When Ben was not assisting a group with a question, he moved from group to group and observed his students. He was usually available for assistance. When several groups of students had similar difficulties, he began to lecture, addressed the situation, and
returned students to small group work. This was more often productive than not productive. He used the chalkboard quite often when explaining concepts to either the whole class or specific groups.

Small groups generally performed the tasks assigned when Ben asked the students to work collaboratively. Students actively shared and collaborated. However, there were some groups that had difficulties staying on task. They worked productively for a few minutes, digressed to a "non-calculus" subject, and then returned to the calculus matter at hand.

Three Caucasian students from Ben’s calculus class were interviewed about small group work: (1) a junior female (Student 1) majoring in microbiology and mathematics, (2) a sophomore male (Student 2) majoring in civil engineering, and (3) a freshman male (Student 3) majoring in electrical engineering. All interviewees believed that Ben selected and structured the small groups fairly. Student 2 disliked small group work because his group did “too much screwing around.” He wished Ben used “more goal oriented” small group work. Student 2 had little previous experience with collaborative learning. Students 1 and 3 had some previous experience with collaborative learning, enjoyed small group work,
and liked the way Ben organized class time. All student interviewees believed that Ben was comfortable facilitating small group lessons and enjoyed teaching calculus.

Clyde

Clyde was a second year graduate student in the Master’s mathematics program at MSU-Bozeman. He planned to either teach or continue his education at the doctoral level. Clyde enjoyed teaching but admitted that his main reason for teaching was to earn money while being a graduate student. Clyde stated that he enjoyed teaching and planned to teach in a small four-year school. He did not want to be a research mathematician. None of the instructors in this study planned to become research mathematicians in situations where teaching was de-emphasized.

Clyde was exposed to the Harvard program in Colorado before attending MSU-Bozeman. He tutored students during recitation sections. Clyde commented that the recitations “really weren’t group work, but they did group work in class.”. He had a few experiences with small group work during the instruction of a pre-calculus class
at MSU-Bozeman. Clyde had never experienced group work in high school but had experienced a little group work at the collegiate level.

Clyde’s afternoon class contained 32 students. A summary of the characteristics of the participating students by gender, ethnicity, class, and major is in Table 1 in Appendix J. Twenty-seven students (twenty-two males and five females), approximately 84% of Clyde’s class, participated in the study. Clyde’s class had the largest percentage of student involvement in the study. The other five male students were not included in the study because they failed to complete all three questionnaires. These five students received “C” grades or better on the final examination. Of Clyde’s students participating in the study: (1) twenty-two were freshmen, (2) fourteen were engineering majors, and (3) nine were computer science majors. All students were Caucasians except for one Asian male.

Clyde formed the student groups randomly (where the students were seated) and by student preference. Clyde regrouped the students that requested a change due to their major or the kind of calculator they used. “It was also a little bit of mix and match by personality - who I thought could work well together.” Student
gender was not considered but the Asian male was considered. Clyde commented: “I wanted to make sure [the Asian male] wasn’t with a really obnoxious group, because he was a soft-spoken guy.” Clyde considered student ability when forming groups because he had “already assessed the good and bad students.” Small group sizes were three or four students except for one group that had two students.

Clyde predicted that he would use collaborative learning for approximately 100 minutes a week. However, the data revealed that he used small group work for approximately 50 minutes per week. Clyde was the only instructor who predicted that he would use more small group work than he actually did. Information in Table 2 (Appendix I) shows the breakdown of Clyde’s total class time. He lectured 59% of the time and utilized small group work 21% of the time. Clyde spent 9% of class time reviewing for tests.

Clyde routinely used small group work on Wednesdays. Sometimes he used small group work when “introducing an idea at the beginning of class.” Thus, it was important that students sat in their groups during lecture and small group work. Clyde said: “I want them sitting relatively close because every once in a while we’ll
bust up into groups for maybe three minutes and it would take that long to move around if they weren’t sitting next to each other.”

Clyde could be categorized as an active lecturer (questioning students and promoting class discussion). He liked to question students when they did not volunteer information.

Clyde liked the idea of quizzes, but never found the appropriate time to use them. Students’ homework grades were solely determined by their graded homework problems. He went over proper write-ups “with a fine-toothed comb” prior to the first collection of written work. Clyde used the overhead projector to display proper student write-ups to homework problems. He used the overhead display unit every week - more than any other instructor. Clyde used the overhead projector to display small group and weekly homework assignments.

By midterm Clyde was still going over homework thoroughly. He assigned and graded a large amount of homework using a check system. He did not want to discourage a student from succeeding due to a bad homework grade. During the observations Clyde never graded small group work. During small group work, students were expected to discuss the homework problems and “understand the
problem, where it’s going, what it means, and make sure everyone
has it down.” He did not want them to simply write up the problems,
but rather understand the problems.

Clyde asked students to work on homework problems during small group time. Information in Table 3 (Appendix J) shows the weekly observation schedule for Clyde’s class. Data in Table 4 (Appendix J) shows Clyde’s observation summary. The collaborative learning observation checklist is in Appendix B. On average, 26 students participated in small group work during the observations. The number of students participating in small group work ranged from 18 to 34 students. Clyde utilized small group work between 25 and 50 minutes per class time. The average amount of time spent in small groups was 42 minutes.

Clyde always indicated the objectives and directions for small group work. He introduced group lessons 50% of the time and seldom provided closure to group lessons. Students were always engaged in solving homework problems during small group work. Students were always working to understand many concepts, not just one or two concepts.
Clyde maintained eye contact with small groups when addressing student questions. Eye contact was a positive characteristic of Clyde's "active lecturer" and small group facilitator roles. During most student questions, Clyde intently listened and watched the student share his/her thoughts on a problem before responding to the student question. He was always moving from group to group to assist students and was always available for assistance. When Clyde became involved with student questions he was not always able to observe the other students. Clyde almost always mini-lectured to groups when questions arose and was always able to visit each group in the course of a class period.

Clyde's students asked many more group questions than individual questions. The number of student questions ranged from four to ten. Students asked an average of six questions per observation. Clyde gave direct responses when responding to small group questions. He answered student questions with questions. However, Clyde almost never responded solely to individual students in a group. Clyde responded to student work by saying: "Way to go!" "Good!" and "All right?" Sometimes Clyde responded: "That's a good question." or "Explain it to him (nodding in the direction of another
group member).” Some of Clyde’s questions were: “Do you agree (pointing to another group member)?” “What if I do this...?” or “What do I do next?” However, Clyde seldom asked the groups if other group members knew a solution to the problem before he assisted the group.

Clyde’s students generally kept notes and recorded information as well as performed the tasks assigned to them. Students were usually motivated and sharing ideas, even when they tended to work individually. Students did not always actively collaborate or explain concepts to other group members. Since Clyde’s students often worked individually on problems, they would share solutions to problems instead of collaborating on the same problems.

Some group members had difficulty sitting in tight circles and staying on task. Clyde did not always encourage collaborative work or reinforce positive group behaviors. During the fifth observation of Clyde’s class this researcher noted:

After class I spoke to Clyde. He had told his students prior to class that they could change their group structure if they wanted. He said that some were wanting or looked like they wanted a change. He expects 2 or 3 students to move to another group. He feels that he will slack off a bit and not pressure them to work in their groups. He doesn’t want to baby-sit them. He wants to give them more control of their groups - what and how much they do.
Clyde was an easy-going person who wanted to involve students in small group work. He asked that students not come to class during small group work if they were not serious about solving calculus problems. Thus, there were many times when it was evident that student groups had absent members. Students seldom arrived early for class, but on several occasions students left early from class. Students almost never worked alone during small group time.

Three Caucasian students from Clyde's calculus class were interviewed about small group work: (1) a freshman male (Student 1) majoring in architecture, (2) a freshman male (Student 2) majoring in civil engineering, and (3) a freshman male (Student 3) majoring in civil engineering. All students interviewed believed that Clyde selected and structured the small groups fairly. Students 2 and 3 were content with the amount of time allotted to lecture and collaborative learning. Student 1 recommended that students have more time for small group work.

All student interviewees had some previous experience with small group work. Student 3 had taken calculus in high school where
students were always in small groups during instruction. Students 1 and 2 had used collaborative learning in many high school courses.

Students 1 and 3 believed that Clyde enjoyed teaching and was comfortable facilitating small group work. Student 3 stated: “I think he’s very comfortable teaching it (small group work).” He also commented: “[Clyde’s] lectures are not like other lectures. He asks a lot of questions and we’re a lot more involved. He’s more active. It’s easier to sit through an active lecture.” Student 2 believed that Clyde enjoyed teaching, but was not sure if his instructor was comfortable facilitating small group work. He commented:

[Clyde] made a comment the other day that he didn’t like to do group days because some people just skip class and they just expect the other members of their group to do the work.

Clyde enjoyed facilitating small group work when students were in attendance and serious about solving problems.

Dan

Dan had recently completed his doctorate in mathematics. He defended his dissertation during the course of this study. He planned to find employment teaching at a university or college. Dan
became a graduate teaching assistant to help finance his college endeavors. He normally liked teaching, but said:

It depends a lot on the class. Some classes are more motivating. I guess that depends a lot on how much time I put into preparing it. If they're interested in learning then it is fun to teach. And you get some classes where it's fun to teach.

Dan had little previous experience with collaborative learning. He said he might have had some small group work in high school. He remembered a computer class where students wrote programs in groups. He had never used collaborative learning as an instructor.

Dan's afternoon class contained 40 students. A summary of the characteristics of the participating students by gender, ethnicity, class, and major is in Table I in Appendix I. Twenty-four students (nineteen males and five females), 60% of Dan's class, participated in the study. The participating students completed all three questionnaires and the comprehensive final examination. Of Dan's students participating in the study: (1) all were Caucasians, (2) thirteen were freshmen, (3) eight were sophomores, (4) thirteen were engineering majors, (5) six were science majors, and (6) five were computer science majors. Of the sixteen students not participating in the study: (1) fifteen were males, (2) one female received a "B" final examination grade, (3) seven males received "C"
final examination grades, and (4) five males received "F" final examination grades.

Dan was preparing to finish his dissertation and begin the job hunt when he was called to instruct this section of first semester engineering calculus. He started teaching the course nine days into the semester, following the abrupt leave of another graduate teaching assistant already involved in this study. The course supervisor and researcher’s committee members agreed to the inclusion of Dan in the study. All the other instructors had taken the collaborative learning workshop just before the semester began. Dan received special training from the course supervisor and this researcher in order to provide him with a collaborative learning background which was, as nearly as possible, the same as the other instructors. Dan was given all the handouts and notes of the previous workshop. Dan participated in this study in the same manner as all the other instructors.

Since Dan entered his teaching assignment late, student small groups had already been formed. Dan assumed the same groups as the previous instructor (the previous instructor was also a Caucasian male and in the doctorate program in mathematics). Since Dan
entered this study during the time when students were dropping and adding classes, he had to restructure some groups. Group sizes were four members because Dan believed that "if you get too many people in a group it's too easy just to sit aside and let the rest of the group work." Students interviewed in Dan's class recalled that the groups had initially been formed randomly. Students were asked to form groups with other nearby students. Personal preferences might have been involved in the initial construction of the groups. Once groups had been formed and Dan became the instructor, he asked the groups to get into circles whenever they were involved in group work. Students generally sat in the same vicinity, whether listening to a lecture or working in groups.

Dan lectured to his class 64% of the time, while he utilized collaborative learning 24% of the time. Information in Table 2 (Appendix J) shows how Dan's class compared to the other five classes in breakdown of total class time. This information was obtained from each instructor's weekly collaborative learning log (Appendix G). During Dan's midterm interview he stated: "Probably about one hour a week is collaborative learning and the rest of the
time is lecture.” His statement was close to the actual data he had provided in his weekly logs.

On Mondays, Dan issued the weekly homework assignment and on Fridays he gave a quiz based on the assigned homework. Dan generally lectured on the calculus concepts before utilizing small group work. He said: “Once in a while, when we’re caught up on lecture, I’ll have a group day so that gives them a chance to get caught up on their homework.” Some weeks he had more small group work than other weeks, especially when reviewing for a test. Dan collected graded group work during only one of the nine times he was observed. He always graded the weekly ten-point quizzes which were given on Fridays. He said: “I’d like to think that the quizzes are motivating the homework, because I’ll pull a problem from the homework.”

Information in Table 3 (Appendix J) shows the weekly observation schedule. Dan was observed for the first time during week four, because of his late entrance into the study. Dan used small group work when students needed time to work on homework or review for a test or quiz. Students used small groups to review homework problems for a quiz or test 50% of the observed time.
Many times Dan followed the small group homework review by the 30-minute weekly quiz which happened on Fridays. Student attendance was high during these days. Small group time was 20 to 25 minutes during these small group review sessions. Dan usually allowed anywhere from 20 to 50 minutes for small group work, but the average time was 35 minutes. Dan had the lowest average time for small group work. Generally, 32 to 38 students were involved during small group work. Dan’s class averaged 35 students participating during group time. Data in Table 4 (Appendix J) shows the observation summary.

Dan always gave clear directions to the students during group work. Objectives for the assignments were seldom given. Students generally understood what “review of homework” on Fridays implied. Dan was observed to introduce the group lessons 50% of the time. Dan never closed a group work lesson nor used a small group quiz. Students participating in small group work were observed discussing many calculus concepts, not just one concept.

Students sometimes sat in close circles during small group work. Students in the back row of the classroom often sat in a line or in “horseshoes.” Students in groups of three or four generally did
more pairing-and-sharing than working together as a whole group. The class was large and on Fridays when all the students arrived to take the quiz, the room was full. It was difficult for groups to form circles when more than 35 students were seated in small groups. During small group work prior to a quiz, students were generally motivated, discussing problems, sharing ideas, and cooperatively working on the material. Students seldom took notes or recorded work when reviewing for tests and quizzes. Usually, Dan’s students did not actively collaborate when working together, since homework problems were often solved individually and then compared during small group time. Because of the individual work, collaborative learning happened when the problems were checked. For example, students in Dan’s class typically checked homework solutions and answers during the twenty minutes prior to Friday’s homework quiz. During this time there was much student participation and the noise level was high. During the small group sessions the questions directed to Dan were usually group questions. The individual questions were usually asked during test reviews and the completion of homework.
Dan's class had a problem with students leaving early during test reviews and completion of homework. Several students often arrived late for class on Friday's quiz day. These students did not attend the small group time and only participated in the quiz. Dan is an "easy going guy," as one student put it, and students always seemed to be coming or leaving. Since Dan usually motivated small group work with such incentives as reviews for quizzes or review sheets for tests, group members were usually present during at least part of the class. During the eighth observation this researcher noted:

On group work day this class has always been a come-and-go type of class where students arrive late, leave early, take the quizzes early, etc. Dan is very easy going and doesn't show that these [student behaviors] bother him (if it does). So, students might think that it doesn't [bother him] and that it is OK - I don't know if he has ever said one way or the other.

Dan moved from group to group as questions arose. He listened to the students' questions, their explanations, and then he discussed the problems with them. Dan seldom made direct eye contact with the students as he listened and responded to their questions. He almost always studied the students' homework papers and textbooks instead of making eye contact with the students themselves. He almost never answered student questions with questions, but gave
direct responses to the students. He made comments like: "Yes" or "Right" and gave directions by saying: "You can do this..." or "So it is going to be..." Sometimes he said: "No, think of it this way..." if students were on the wrong track. It seemed difficult for Dan to observe the groups when he was responding to student questions. Therefore, he did not seem to be aware of the entire classroom and this made it easy for students to leave. He was always available for assistance, but seldom mini-lectured to student groups. He usually spoke to students individually by direct response.

Dan's students asked him between 3 and 11 questions during the observed small group times. The average number of student questions was six for the entire class. Dan sometimes spent 5 to 10 minutes with students as they explained their questions and problems. He never asked small groups whether one of the student members knew the solution before he addressed a question. Dan was seldom able to visit each group during the course of a period. He facilitated small group work, but did not necessarily encourage it or reinforce positive group work behaviors. Dan responded positively to small group work, but was often quiet and easy-going in class.
Students were unable to determine whether their instructor was positive about small group work.

Three Caucasian students from Dan’s calculus class were interviewed about small group work: (1) a freshman female (Student 1) majoring in chemical engineering, (2) a freshman male (Student 2) majoring in electrical engineering and computer science, and (3) a freshman male (Student 3) majoring in electrical engineering. All students interviewed believed that Dan selected and structured the small groups fairly. Student 1 commented: “[The structure of my group] works really good. We’re all at different levels, too, so a lot of times we’re helping each other.” She stated that her group consisted of two females and two males. She stated: “I think it’s better for me that there’s another girl in the group because I don’t feel well [in a group with all males] - it’s just more beneficial, with guys’ attitudes and everything.”

All students interviewed had some previous experience with collaborative learning. Students 1 and 3 participated in small group learning in high school. Student 2 had previously taken calculus in high school but liked to study and work problems individually. He seldom attended class except to take and pick up completed quizzes.
All students interviewed differed in their opinions about the amount of time allotted to small group work. Student 1 recommended that Dan use more small group learning in class. She stated: “I think we should be able to get with our groups more at the end of class. I think we should be able to do our homework together in groups.” Student 2 believed that there was adequate time allotted to small group work. He preferred lecture, but stated: “If I was in class [and] really struggling, then I would really enjoy the group work.” Student 3 was satisfied with the time allotted to collaborative learning.

All interviewees believed that Dan liked teaching calculus. The students seemed unclear about whether or not Dan was comfortable using collaborative learning. Student 1 stated: “He seems OK with it;” Student 3 commented: “I think he is [comfortable facilitating small group work];” and Student 2 commented: “I’m not sure how he feels about it. I don’t think he minds us working in groups. He goes around and answers questions in the small groups.”
Ellen

Ellen was in her first year of the doctoral program in mathematics at MSU-Bozeman. She was using the graduate teaching assistantship strictly as a means to pay for college. She did not plan to have a career in teaching. Ellen stated:

At times I enjoy teaching and I realize that if I go on to a university I may be doing some teaching, but, that isn't something I'm looking for - I'd actually prefer working in industry or the private sector. I've worked there before.

Ellen worked in small groups on homework in many of her undergraduate engineering classes. At times, homework was completed by the group and turned in as a group. She took one graduate mathematics course where the instructor assigned homework buddies, but since she liked to work on her own she did not work with her partner. As an instructor, this was her first experience with the use of collaborative learning.

Ellen's afternoon class contained 38 students. A summary of the characteristics of the participating students by gender, ethnicity, class, and major is in Table 1 in Appendix J. Twenty-three students (seventeen males and six females), approximately 61% of Ellen's class, participated in the study. The participating students completed
all three questionnaires and the comprehensive final examination. Of
the participating students: (1) fourteen were freshmen, (2) seven
were sophomores, (3) fourteen were engineering majors, and (4) four
were science majors. Of Ellen's students not participating in the
study: (1) twelve were males, (2) three were females, and (3) eight
males received "D" grades or lower on the final examination. One
African, two Asian, one Native American, and 35 Caucasian students
were enrolled in Ellen's class. Two Asian and 21 Caucasian students
participated in this study.

Initially, Ellen asked the students to work in groups and solve
problems that were never graded. She observed the students to see
if "personalities were clashing and who was working well together"
and who she had to separate. After the first examination she split up
"clashing" or "chummy" groups. At that time she also assembled
groups on the basis of ability level. Those students of similar ability
level (measured by the first examination) were put in groups of four.
Ellen commented:

The reason I grouped by ability level is because after the first
exam (I thought it was sort of easy) if someone didn't do well
on that exam they would probably not do well in the course
and I didn't want to saddle a group where that person may be
dropping.
She also considered gender when forming groups. “I tried to make sure every female had at least one other female in the group.” By the end of the semester most groups were of size four or five with a few groups being size three due to withdrawals.

Ellen used lecturing 67% of the time while utilizing collaborative learning 20% of the time. Information in Table 2 (Appendix I) indicates that she lectured more than any other instructor. Ellen generally had 50-minute group days that sometimes continued the following day. She had accurately predicted she would use collaborative learning for approximately 50 minutes per week.

Ellen gave quizzes that accounted for 6% of the total class time. These quizzes were announced ahead of time. They were used as short assessments of students’ abilities. Ellen also graded student group work and portfolios or notebooks of student homework. She, along with several other instructors, asked their students to keep their homework problems in binders or notebooks for easy reference. Ellen collected these portfolios and graded a few select problems. Thus, Ellen assessed the students regularly and more often than the other instructors.
Ellen was also a “stickler on neatness” when assessing student homework. During group work, Ellen observed students to see if they were talking to one another and discussing what they thought about the problems. She moved from group to group to:

quiz them on where they’re at and what they’re doing. I don’t like to just sit back and let them work in groups because it seems to me that one kid in the group either doesn’t discuss or is left behind and not included in the group work.

When students completed group work, they handed in their solutions with a cover letter outlining everyone’s responsibilities for that day.

Ellen tried to “structure the group work as much as possible.” She assigned groups labels (A through J) and seating assignments. Ellen wanted to get them in the habit of putting their chairs in a circle, facing one another, in order to talk to one another. Since student groups were arranged by Ellen during the first few weeks of the semester, group members did not sit by one another during periods of lecture. Ellen stated that “it’s really mixed up because the chummy ones I split up (for group work) sit together on lecture days.”

Information in Table 3 (Appendix J) indicates the weekly observations for Ellen’s classes. Data in Table 4 (Appendix J) shows the observation summary for Ellen. Note that Ellen occasionally had
more students involved in group work than were enrolled in her class at the end of the semester. Ellen's enrollment exceeded 40 students at the beginning of the semester.

From the nine observations, Ellen averaged 47 minutes for small group work. Ellen preferred to utilize small group work for an entire period, using this time for extended or more complex group problems. Ellen used small group work on various days of the week. She was observed to use group work more on Tuesdays and Fridays. She seldom used group work to emphasize a single concept, but emphasized many concepts in any one group assignment. Students engaged in small group work to: (1) discuss homework problems during 45% of the observations, (2) find solutions to complex group problems during 45% of the observations, and (3) complete textbook problems in review for a test during 10% of the observations. Group work objectives and directions were always made clear by Ellen verbally or in writing on the chalkboard. Group lessons were introduced 50% of the time. Closure to group lessons were seldom provided. Ellen always moved around the room from group to group and almost always observed group members when she was not answering questions. She was always available to give assistance.
During several observations, class time ran out before she could answer all of the student questions. Ellen occasionally responded to student questions by saying: “What if you’d do this...” or “Think of it in this way...” If students needed more direct responses she said: “You need to do it this way...” Ellen had a tendency to give more direct answers to student questions rather than answering student questions with questions. Questions were usually from student groups. Occasionally, individual students asked questions. Students normally asked Ellen anywhere from 7 to 19 questions (either individual or group) during the course of a class period. The average number of questions asked during the nine observations was eleven. When questions were asked of Ellen (whether individual or group) she almost always addressed the whole group with her response. As the semester progressed more student questions became individual questions and Ellen responded to the individual, not to the group.

Eye contact did not seem to be easy for Ellen. Ellen rarely made eye contact with her students during periods of lecture and small group work. She seldom made eye contact with students when questions were asked. Ellen usually studied student homework papers when student questions were asked.
During some observations, Ellen was quite positive about collaborative learning and other days she was discouraged about small group work. This was apparent in her discussions with this researcher as well as in the classroom. Ellen commented that her calculus students had many different personalities and many of them clashed with her own. In her opinion, it was an unusual mixture of students. During discouraging days, Ellen used less eye contact and responded to individual student questions individually and more directly. During a majority of Ellen's productive small group periods she questioned students by asking the groups: "What are...?" or "What is...?" to assist the students in communicating with their peers.

Ellen was always able to move around to all groups during small group time. During the last few observed sessions, Ellen provided less encouragement for positive small group behaviors. Ellen changed small group work strategies during the semester. During week five, Ellen discussed with her students the new rules for writing papers during small group work. She gave them more "structured" rules. During the final weeks of the semester (starting with week eleven), Ellen indicated that she allowed more individual student work when students worked in small groups. During these
times, Ellen asked such questions as “Are you getting it and checking with one another?” or “What do you mean by...?” These questions primarily addressed individuals, but prompted the students to communicate with their peers.

Students in Ellen’s class were always writing and keeping notes during small group work. Students seldom arrived late or left class early. Also, they seldom worked alone. Ellen’s class attendance was sometimes smaller than the enrollment figures. All the students who attended class participated in small group work and were almost always motivated. They were seated in tight circles, performing their tasks, and cooperating socially on the assigned problems. Small group work assignments were usually long and complex which likely lessened student discussion on “non-calculus” issues. Ellen, like Al, assigned problems from other sources besides the textbook.

Three students from Ellen’s calculus class were interviewed about small group work: (1) a junior Caucasian male (Student 1) majoring in biology and medicine, (2) a sophomore Caucasian female (Student 2) majoring in architecture, and (3) a freshman Asian male (Student 3) majoring in general studies and planning to pursue civil engineering. All students interviewed believed that Ellen selected
and structured the small groups fairly. The two male students believed that Ellen should have had more small group work. Student 3 stated:

She could give us a little more group work time because sometimes we don’t manage to finish it [the assignment] in class. You have to hand it all in at the end of class and sometimes you don’t have it done. She assigns kind of hard problems because it’s a group effort.

Student 1 commented: “There should be more of the group work but I’d like to have more lecture.” Student 1 had little previous experience with collaborative learning while Students 2 and 3 had more previous experience with small group work.

When asked if Ellen was comfortable facilitating collaborative learning, Student 3 responded:

I don’t know. She’s a graduate student who’s just teaching. I guess she’s just trying it out to see what it’s like. I don’t know if she’s done it before but it seems like she’s just trying it out [small group work] to see what happens.

Student 1 responded:

Sometimes yes and sometimes no because I think it’s brand new to her too. She tries very hard. She goes around and works with each group, but sometimes she doesn’t get around to all the groups. She knows her stuff and if we ask her a question she doesn’t know, she finds the answer and brings it back the next day.

Student 2 responded:
I guess she seems comfortable. I don’t think she’s done much of it because she tries to structure it so much where we have to write everything...

All students interviewed believed that Ellen enjoyed teaching.

Fran

Fran was a mathematics graduate student in the doctoral program at MSU-Bozeman. She planned to teach at a college where mathematics teaching was the focus. Fran enjoyed teaching but admitted that her main reason for teaching was to earn money while being a graduate student.

Fran had never taught using collaborative learning, but had used it in undergraduate English. She also formed her own study groups during graduate mathematics classes. She said:

It’s nice to have someone to bounce ideas off of, but it also has to be with someone that I trust. It can’t be with someone that I forced into it. It’s not just personality but also there has to be some respect as far as students go. It’s coming to the table both prepared and as equals. Unfortunately those situations are very few because you have to find those few people who you can do that with.

Fran’s morning class contained 39 students. A summary of the characteristics of the participating students by gender, ethnicity, class, and major is in Table 1 in Appendix J. Twenty-four students
(seventeen males and seven females), approximately 62% of Fran’s class, participated in the study. The participating students completed all three questionnaires and the comprehensive final examination. Of the students participating in the study: (1) all were Caucasians except for two Asian males, (2) twenty were freshmen, (3) thirteen were engineering majors, and (4) six were science majors. Of Fran’s students not participating in the study: (1) eleven were males, (2) four were females, and (3) eight received “D” grades or lower on the final examination.

Fran “did absolutely no structuring” in the forming of groups. She stated: “I told them we were going to work in groups and you pick the people you want to work with.” She told them that group sizes were three or four members. Since students picked their own groups, they had a tendency to sit by their groups on lecture and group work days. Fran was a very active lecturer. Fran asked individual students questions during the lectures to promote class discussions.

Fran utilized small group work on Thursdays. All of Fran’s observations were performed on Thursdays. Information in Table 2 (Appendix J) indicates the breakdown of total class time for the
instructors. Fran lectured 66% of the time and utilized collaborative learning 16% of the class time. She also gave quizzes 12% of the class time. Quizzes were given every week, on Fridays, and they covered the week's assigned homework. She had accurately predicted she would use collaborative learning for approximately 50 minutes per week.

During a normal week, Fran lectured on Mondays, Tuesdays, and Wednesdays, facilitated small group work on Thursdays, and administered quizzes on Fridays. Prior to the quizzes, Fran generated a question-and-answer session to review problems on homework. Student homework grades were determined by the weekly 20-point quizzes and the weekly 10-point group assignments. During the first observation, Fran assigned five group work problems. She stated:

Students couldn't get through them so I try to limit them to two group work problems. If they've got any extra time we've made a pact that they do homework and ask each other [questions] on homework.

Subsequently, almost all group work assignments consisted of two (or three) problems. She encouraged nice write-ups on student group work. Fran often used a question-of-the-day to take attendance. Students were asked a question at the beginning of the period "to keep them up on the reading." She stated that "they think
it's counting something when it might not count at all.” Fran said she used these questions when determining “borderline” grades.

Information in Table 3 (Appendix J) shows the weekly observation schedule. During small group time Fran usually entered the classroom and wrote the two small group problems on the board for the students to work. For example, she would write on the chalkboard: “Page 271, #8; page 288, #10.” Fran would then sit at the front table as the students formed groups. Students were told a week in advance which day would be set aside for small group work.

Data in Table 4 (Appendix J) shows the observation summary of Fran’s class. The collaborative learning observation checklist is in Appendix B. Fran’s students were involved in small group work an average of 47 minutes during the fifty minute class period. Fran’s students were never engaged in small group work for less than 40 minutes. The number of students attending class on observed group days ranged from 25 to 39 students with an average number of 37 students present.

Fran seldom provided introductions and closures to small group lessons. The directions for small group work had been given and made clear to the students during the first small group session. Fran
indicated the objectives for small group work 50% of the time. During small group sessions, students worked on small group problems to understand one or two specific concepts 50% of the time.

Students in Fran’s class were usually seated in tight circles, performing tasks, sharing ideas, and cooperatively working on calculus. Fran encouraged her students to work on homework once the small group work was completed. Students in Fran’s class were usually motivated and working collaboratively. Fran’s students would sometimes pair-and-share when working to complete a group assignment. Fran’s students tended to share or help a partner rather than help their whole group. This was reflected in the number and kinds of questions students asked their instructor. Fran’s students asked approximately 50% individual (or pair) questions and 50% whole group questions. An average of eight student questions were asked during a small group session. Fran left the room during four observations for 10 to 15 minutes. During these observations, fewer than six student questions were asked. Because of Fran’s absences from class, she was not always available for assistance. During the final observation of Fran’s class this researcher noted:

Fran left the room for the first 20 minutes as students worked. When she returned, she didn’t help them as they asked
questions [because] it was a quiz - not homework. After she helped with four student questions she read a newspaper for 10-15 minutes. She was available 50% of the time and of that time she was not observing or helping much because it was a student quiz.

When Fran was present for small group work she sometimes graded student papers or worked on her own mathematics homework. She usually did not observe her students during small group time. When a student asked a question during small group time Fran would answer it and then move around the room and answer other student questions. Fran visited all student groups about 50% of the class time.

Fran’s students were often observed taking notes and writing solutions to problems. Students in Fran’s class were held accountable for their small group work. Students in Fran’s class never worked alone. Fran’s students seldom arrived late to class or left class early.

When answering student questions, Fran maintained eye contact and usually answered student questions with questions. She maintained eye contact with whole groups even when individual student questions were asked. Eye contact was a positive characteristic of Fran’s “active lecturer” and small group facilitator roles. Fran answered more student questions with questions than
the other instructors. Fran responded to student questions when it was appropriate. Fran's common responses were: "Good job!" "How's it going?" "Keep going with this." "Why?" "Explain." "What's true about...?"

Fran rarely responded to individual students when student questions were asked. Fran usually mini-lectured or addressed whole groups when individual students asked questions. She would often ask a group if any member knew the solution to a problem before she addressed the entire group. Fran reinforced positive group work behaviors, but because of her several absences, it was not apparent that she always facilitated collaborative learning.

Three Caucasian students from Fran's calculus class were interviewed about small group work: (1) a junior male (Student 1) majoring in physics, (2) a freshman male (Student 2) majoring in microbiology, and (3) a freshman male (Student 3) majoring in civil engineering. All students interviewed believed that Fran selected and structured the small groups fairly. They approved of the random formation of small groups. They were satisfied with the time allotted to lecture and small group work.
All students interviewed had some previous experience with collaborative learning. Student 1 had previously used small group work in first semester engineering calculus. Student 3 had previously taken calculus in high school where “we did pretty much what we’re doing [now] in [first semester engineering calculus].”

The student interviewees had mixed opinions of Fran’s enjoyment of teaching and collaborative learning. Student 3 believed that Fran was comfortable facilitating small group work and enjoyed teaching calculus. Student 2 said: “I think she’s pretty comfortable with it [small group work].” However, he stated:

She seems to be a tad bit uncomfortable teaching. I don’t know if she’s taught a lot or what. She seems a little nervous when she’s lecturing. I think she’s more comfortable when we’re doing groups.”

Student 1 said: “I think she enjoys it [teaching] a lot. She’s energetic and really knows what she’s doing.” He commented that Fran seemed to be comfortable facilitating small group work because “it didn’t seem to bother her.”

Quantitative (Statistical) Analyses of Hypotheses

The analysis of variance (ANOVA) statistical test was performed on the students’ final examination scores to determine
whether or not the section averages were statistically different. Tables 5 and 6 display summaries of the participating students’ grades on the comprehensive final examination. Data in Table 7 shows the One-Way ANOVA results. The ANOVA test was analyzed at the $\alpha = 0.05$ level of significance. The ANOVA results indicate a p-value of 0.098 which is not statistically significant at the $\alpha = 0.05$ level of significance. Therefore, the students’ final examination scores are not statistically different between sections.

Table 5: Section Summary of Student Final Examination Grades by Gender

<table>
<thead>
<tr>
<th>LETTER GRADES</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instructor</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>Al</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Ben</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Clyde</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>Dan</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Ellen</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Fran</td>
<td>5*</td>
<td>6</td>
</tr>
</tbody>
</table>

* One student is Asian
# Two students are Asian
Table 6: Student Comprehensive Final Examination Grades (Percentages)

<table>
<thead>
<tr>
<th>Instructor</th>
<th>Number of students participating in the study</th>
<th>Range of students' final examination scores</th>
<th>Student averages on final examination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al</td>
<td>15</td>
<td>61.5 - 98.5</td>
<td>83.67</td>
</tr>
<tr>
<td>Ben</td>
<td>20</td>
<td>52.5 - 100</td>
<td>82.25</td>
</tr>
<tr>
<td>Clyde</td>
<td>27</td>
<td>40.0 - 99.0</td>
<td>78.80</td>
</tr>
<tr>
<td>Dan</td>
<td>24</td>
<td>51.0 - 93.5</td>
<td>74.33</td>
</tr>
<tr>
<td>Ellen</td>
<td>23</td>
<td>41.5 - 93.5</td>
<td>76.07</td>
</tr>
<tr>
<td>Fran</td>
<td>24</td>
<td>41.5 - 98.0</td>
<td>84.13</td>
</tr>
</tbody>
</table>

Table 7: One-Way ANOVA Results

<table>
<thead>
<tr>
<th>SUMMARY</th>
<th>Count</th>
<th>Sum</th>
<th>Average</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Section</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Al</td>
<td>15</td>
<td>1255</td>
<td>83.67</td>
<td>161.77</td>
</tr>
<tr>
<td>Ben</td>
<td>20</td>
<td>1645</td>
<td>82.25</td>
<td>224.91</td>
</tr>
<tr>
<td>Clyde</td>
<td>27</td>
<td>2127.5</td>
<td>78.80</td>
<td>235.58</td>
</tr>
<tr>
<td>Dan</td>
<td>24</td>
<td>1784</td>
<td>74.33</td>
<td>206.54</td>
</tr>
<tr>
<td>Ellen</td>
<td>23</td>
<td>1749.5</td>
<td>76.07</td>
<td>174.67</td>
</tr>
<tr>
<td>Fran</td>
<td>24</td>
<td>2019</td>
<td>84.13</td>
<td>147.54</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ANOVA</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>1850.11</td>
<td>5</td>
<td>370.02</td>
<td>0.0978</td>
</tr>
<tr>
<td>Within Groups</td>
<td>24651.82</td>
<td>127</td>
<td>194.11</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>26501.93</td>
<td>132</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The data reported and analyzed in this section are arranged according to the five null hypotheses stated in Chapter 2. These null hypotheses were tested at the $\alpha = 0.05$ level of significance. P-values
were used to determine whether the null hypotheses were rejected at the $\alpha = 0.05$ level of significance.

**Hypothesis 1**

There is no statistically significant relationship between the dependent variable (student achievement on a comprehensive final examination) and the collective contribution of the independent variables (the calculus section effect, students’ perceptions of collaborative learning, and students’ perceptions of their instructors’ views of collaborative learning).

Hypothesis 1 was rejected at the $\alpha = 0.05$ level of significance. With a p-value of 0.0234, there was a statistically significant relationship between the dependent variable (students’ comprehensive final examination scores) and the collective contribution of the independent variables (the calculus section effect, students’ perceptions of collaborative learning, and students’ perceptions of their instructors’ views of collaborative learning). The best model (Model 3) indicates that 17% (R-Square Adjusted = 0.1678) of student final examination score variability is explained when clustering the questionnaire data (students’ perceptions of
collaborative learning, students' perceptions of their instructors' views of collaborative learning) and the calculus section effect.

The cluster of questionnaire data used to measure students' perceptions of collaborative learning in Model 3 were:

2. When I work in a group I produce better quality work.
13. I wish our class would have lots of group work time.
17. I dislike it when my individual grade is tied to group work.

Questionnaire item 4 was also used to measure students' perceptions of collaborative learning in Model 3:

4. I like having "smart" people in my group.

The cluster of questionnaire data used to measure students' perceptions of their instructors' views of collaborative learning in Model 3 were:

22. My instructor uses a good balance of group work and lecture.
28. My instructor feels that it is important to teach students how to communicate.

Questionnaire item 27 was also used to measure students' perceptions of their instructors' views of collaborative learning in Model 3:

27. My instructor feels that some group members rely too heavily on their peers during group work.
Hypothesis 1 was tested using the collected data from the students’ third questionnaire (Questionnaire 3). For statistical purposes, the numerical values of questionnaire items 4, 17, and 27 were reversed. The calculus section effect (section number of an enrolled student) was used to take into account section differences.

Information in Table 8 shows section averages on student questionnaire items 2, 4, 13, 17, 22, 27, and 28. A p-value of 0.0126 was calculated on the One-Way ANOVA test for questionnaire item 22. This indicates that there were section differences on student questionnaire item 22. There were no section differences for questionnaire items 2, 4, 13, 17, 27, and 28.

<table>
<thead>
<tr>
<th>Section</th>
<th>Q. 2</th>
<th>Q. 4</th>
<th>Q. 13</th>
<th>Q. 17</th>
<th>Q. 22</th>
<th>Q. 27</th>
<th>Q. 28</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al</td>
<td>3.20</td>
<td>3.60</td>
<td>3.20</td>
<td>3.33</td>
<td>3.67</td>
<td>2.93</td>
<td>3.6</td>
</tr>
<tr>
<td>Ben</td>
<td>3.35</td>
<td>3.90</td>
<td>2.80</td>
<td>3.60</td>
<td>3.45</td>
<td>2.95</td>
<td>3.30</td>
</tr>
<tr>
<td>Clyde</td>
<td>3.11</td>
<td>3.56</td>
<td>2.89</td>
<td>3.52</td>
<td>3.52</td>
<td>3.00</td>
<td>3.44</td>
</tr>
<tr>
<td>Dan</td>
<td>3.17</td>
<td>3.50</td>
<td>2.67</td>
<td>3.75</td>
<td>2.92</td>
<td>3.29</td>
<td>3.29</td>
</tr>
<tr>
<td>Ellen</td>
<td>3.09</td>
<td>3.83</td>
<td>2.83</td>
<td>3.30</td>
<td>3.09</td>
<td>3.17</td>
<td>3.39</td>
</tr>
<tr>
<td>Fran</td>
<td>2.75</td>
<td>3.88</td>
<td>2.38</td>
<td>3.83</td>
<td>3.58</td>
<td>2.88</td>
<td>3.79</td>
</tr>
</tbody>
</table>

There were 29 items on the student collaborative learning questionnaire instrument. Twenty questions corresponded to students’ perceptions of collaborative learning and nine questions
corresponded to students' perceptions of their instructors' views of collaborative learning. Cluster analysis on MINITAB was used to cluster the two subsets of questionnaire items in an attempt to reduce the number of variables in the full model (which used all 29 items). Group A clusters corresponded to students' perceptions of collaborative learning and Group B clusters corresponded to students' perceptions of their instructors' views of collaborative learning. The summary of cluster analyses is in Table 9.

Table 9: Clustered Questionnaire Items

<table>
<thead>
<tr>
<th>First Part Clusters</th>
<th>Second Part Clusters</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1 = 1A, 2, 13, 14, 16, 17, 19</td>
<td>B1 = 1B, 21, 22, 26, 28</td>
</tr>
<tr>
<td>A2 = 3, 5, 6, 20</td>
<td>B2 = 24, 27</td>
</tr>
<tr>
<td>A3 = 7, 8, 9, 10</td>
<td>B3 = 23, 25</td>
</tr>
<tr>
<td>A4 = 12, 15, 18</td>
<td>B4 = 22, 28</td>
</tr>
<tr>
<td>A5 = 4, 11</td>
<td></td>
</tr>
<tr>
<td>A6 = 2, 13, 17</td>
<td></td>
</tr>
</tbody>
</table>

A general linear models procedure (multiple regression) was performed on SAS in an attempt to find a model that best predicted the comprehensive final examination score. Data in Table 10 shows the results of the multiple regression procedure without clusters. These are the full model results. This model served as baseline information for the multiple regression procedure.
Table 10: General Linear Regression Models Procedure Without Clusters (Full Model)

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>Sum Squares</th>
<th>Mean Square</th>
<th>F-Value</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>34</td>
<td>9818.187</td>
<td>288.7703</td>
<td>1.70</td>
<td>0.0234</td>
</tr>
<tr>
<td>Error</td>
<td>98</td>
<td>16683.74</td>
<td>170.2423</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrected Total</td>
<td>132</td>
<td>26501.93</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

R-Square     | c.v.  | Root MSE   | FINAL Mean | R-Square Adj |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0.370471</td>
<td>16.40211</td>
<td>13.048</td>
<td>79.549</td>
<td>0.152506</td>
</tr>
</tbody>
</table>

Multiple regression procedures were then performed using various clusters in an attempt to better analyze the data. The Likelihood Ratio Test was used to compare clustered analyses. Information in Table 11 shows these results.

Table 11: Final Multiple Regression Results With Updated Models

<table>
<thead>
<tr>
<th>Model</th>
<th>Clusters</th>
<th>SSE</th>
<th>DF</th>
<th>R-Sq Adj</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sec#, Q. 1-28</td>
<td>16683.7</td>
<td>98</td>
<td>0.1525</td>
</tr>
<tr>
<td>2</td>
<td>Sec#, A1-A5, B1-B3</td>
<td>21915.9</td>
<td>119</td>
<td>0.0827</td>
</tr>
<tr>
<td>3</td>
<td>Sec#, A6, Q4, B4, Q27</td>
<td>20551.4</td>
<td>123</td>
<td>0.1678</td>
</tr>
<tr>
<td>4</td>
<td>Sec#, A1-A4, 22, 27</td>
<td>20851.1</td>
<td>120</td>
<td>0.1345</td>
</tr>
<tr>
<td>5</td>
<td>Sec#, 2, 4, 13, 17, 19, 22, 27, 28</td>
<td>20483.5</td>
<td>119</td>
<td>0.1427</td>
</tr>
<tr>
<td>6</td>
<td>Sec#, A1-A4, 4, 11, 22, 27</td>
<td>20446.5</td>
<td>119</td>
<td>0.1442</td>
</tr>
</tbody>
</table>

The clustered models (Models 2 - 6) are equivalent to the full model (Model 1). Model 3 in Table 10 is the best fit because the R-Square Adjusted is 0.1678 which indicates that 17% of the variance
in students' comprehensive examination scores can be explained by the calculus section of the enrolled student, students' perceptions of collaborative learning, and students' perceptions of their instructors' views of collaborative learning.

Hypothesis 2

There is no statistically significant relationship between the dependent variable (student achievement on a comprehensive final examination) and the separate contribution of the independent variables (the calculus section effect, students' perceptions of collaborative learning, and students' perceptions of their instructors' views of collaborative learning).

Hypothesis 2 was not rejected when using calculus section effect as the independent variable. Since a p-value of 0.258 was tabulated, there was no statistically significant relationship between a student's final examination scores and the calculus section of the enrolled student.

Hypothesis 2 was rejected when using students' perceptions of collaborative learning as the independent variable. Since a p-value of 0.0052 was tabulated, there was a statistically significant
relationship between students’ final examination scores and students’ perceptions of collaborative learning on questionnaire items 2, 13, and 17. However, this correlation was negative (-24%).

The cluster of questionnaire data used to measure students’ perceptions of collaborative learning were:

2. When I work in a group I produce better quality work.
13. I wish our class would have lots of group work time.
17. I dislike it when my individual grade is tied to group work.

Hypothesis 2 was rejected when using students’ perceptions of their instructors’ views of collaborative learning as the independent variable. Since a p-value of 0.0209 was tabulated, there was a statistically significant relationship between students’ final examination scores and the cluster of questionnaire items 22 and 28. Findings indicate that there exists a positive correlation (20%) between students’ final examination scores and students’ perceptions on the following questions:

22. My instructor uses a good balance of group work and lecture.
28. My instructor feels that it is important to teach students how to communicate.

Since a p-value of 0.0327 was tabulated, there was a statistically significant relationship between students’ final
examination scores and questionnaire item 27. Approximately 19% of final examination score variability was explained due to questionnaire item 27: “My instructor feels that some class members rely too heavily on their peers during group work.”

Hypothesis 2 was tested using the collected data from the students’ third questionnaire (Questionnaire 3). For statistical purposes, the numerical values of questionnaire items 4, 17, and 27 were reversed. The calculus section effect (section number of an enrolled student) was used to take into account section differences. Correlation strengths between each of the independent variables and the dependent variable were calculated.

Calculus section, students’ perceptions of collaborative learning, and students’ perceptions of their instructors’ views of collaborative learning were correlated to students’ final examination scores by utilizing the Pearson r Correlation test on SAS. Information in Table 12 shows the results of the Pearson r Correlation test.

Table 12: Pearson r Correlation Coefficients

<table>
<thead>
<tr>
<th>Correlated:</th>
<th>Sec#</th>
<th>Q. 2, 13, 17</th>
<th>Q. 4</th>
<th>Q. 22, 28</th>
<th>Q. 27</th>
</tr>
</thead>
<tbody>
<tr>
<td>FINAL Correlation</td>
<td>-0.0988</td>
<td>-0.24091</td>
<td>-0.158</td>
<td>0.2001</td>
<td>0.1854</td>
</tr>
<tr>
<td>P-Value</td>
<td>0.2580</td>
<td>0.0052</td>
<td>0.0699</td>
<td>0.0209</td>
<td>0.0327</td>
</tr>
</tbody>
</table>
Table 12 shows specific questions or clusters of questions that correlate with the students’ final comprehensive examination and are significant at the $\alpha = 0.05$ level. These were the only questions or clusters of questions that correlated significantly with students’ final examination scores. Appendix D shows the Student Collaborative Learning Questionnaire and the specific questions that correlated with students’ final examination scores.

**Hypothesis 3**

There is no statistically significant change in instructors’ perceptions of collaborative learning throughout the semester in the reform calculus course.

Hypothesis 3 cannot be rejected at the $\alpha = 0.05$ level of significance. All tabulated p-values were greater than $\alpha = 0.05$. Thus, there was no statistically significant change in instructors’ perceptions of collaborative learning throughout the semester in the reform calculus course.

Each instructor responded to the discrete, Likert-type items on the collaborative learning questionnaire instrument in Appendix C.
This instrument was administered three times during the semester. The Friedman Two-Way ANOVA by Ranks Test is a nonparametric test based on rankings in a randomized complete block design. This test was used to determine whether or not instructors' perceptions of collaborative learning changed throughout the semester.

Each question on the collaborative learning questionnaire instrument was analyzed to see if instructors' perceptions changed throughout the semester on that item. Test statistics for all 35 questionnaire items were calculated and corresponding χ² conversion statistics were found. Corresponding p-values were calculated and compared at the α = 0.05 level of significance. These p-values should not be interpreted as statistically significant. Performing 35 separate tests simultaneously requires the individual tests be performed at an alpha level of 0.05/(2*35) = 0.00071 in order for the overall alpha level to be controlled at 0.05. For all 35 questions, there were no p-values ≤ 0.00071 ≤ 0.05.

Hypothesis 4

There is no statistically significant change in students' perceptions of collaborative learning throughout the semester
Hypothesis 4 cannot be rejected at the $\alpha = 0.05$ level of significance. Thus, there was no statistically significant change in students' perceptions of collaborative learning throughout the semester in the reform calculus course.

The Friedman Two-Way ANOVA by Ranks Test was performed on each question (29 questions) on the student collaborative learning questionnaire (Appendix D) to determine if change occurred in students' perceptions of collaborative learning. Information in Table 13 indicates the questions where p-values were less than $\alpha = 0.05$.

<table>
<thead>
<tr>
<th>Question</th>
<th>Friedman Test Statistic</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A</td>
<td>7.000</td>
<td>0.029</td>
</tr>
<tr>
<td>12</td>
<td>9.083</td>
<td>0.001</td>
</tr>
<tr>
<td>13</td>
<td>9.333</td>
<td>0.006</td>
</tr>
<tr>
<td>16</td>
<td>8.083</td>
<td>0.015</td>
</tr>
<tr>
<td>17</td>
<td>7.583</td>
<td>0.022</td>
</tr>
</tbody>
</table>

P-values for the Friedman test statistic were computed as in the statistical test for changed instructor perceptions.

Each question on the collaborative learning questionnaire instrument was analyzed to see if students' perceptions changed
throughout the semester on that item. Test statistics for all 29 questionnaire items were calculated and corresponding $\chi^2$ conversion statistics were found. Corresponding p-values were calculated and compared at the $\alpha = 0.05$ level of significance. These p-values should not be interpreted as statistically significant. Performing 29 separate tests simultaneously requires the individual tests be performed at an alpha level of $0.05/(2*29) = 0.00086$ in order for the overall alpha level to be controlled at 0.05. For all 29 questions, there were no p-values $\leq 0.00086$.

**Hypothesis 5**

There is no statistically significant difference (for each instructor) between students' perceptions of their instructors' views of collaborative learning and their instructors' stated perceptions.

In all cases except Al's class, Hypothesis 5 was rejected. There were statistically significant differences between students' and instructors' perceptions of collaborative learning in Ben's, Clyde's, Dan's, Ellen's, and Fran's classes. Thus, students' perceptions of collaborative learning were independent of instructors' perceptions.
The data from Al's class indicated that there was not a statistically significant difference between the students' and instructor's perceptions of collaborative learning.

A nonparametric method, called Spearman's Rho Rank Correlation, was used to test Hypothesis 5. Student averages and respective instructor responses on 28 corresponding questionnaire items were ranked. Two subsets of the collaborative learning questionnaire were separately analyzed. Student averages on 19 items reflecting students' perceptions of collaborative learning corresponded to 19 items reflecting instructors' perceptions of collaborative learning. Student averages on 9 items reflecting students' perceptions of their instructors' views of collaborative learning corresponded to 9 items reflecting instructors' perceptions of collaborative learning. Test statistics were calculated for each part on each collaborative learning questionnaire.

The alternative hypothesis for this test is as follows:

$$H_a = \text{Student average response and instructor response tend to decrease or increase together. (That is, the relationship tends to monotonically increase.)}$$

The alpha level for this test is $\alpha = 0.05$. We can reject $H_0$ if the p-value is less than $\alpha = 0.05$, but the probability of making at least
one Type I error is 0.62. To reduce the probability of making a Type I error, the significance level can be modified to \( (0.05)/(2*19) = 0.0013 \) for the first subset of survey questions and \( (0.05)/(2*9) = 0.0028 \) for the second subset. Data in Table 14 shows the results from this test.

<table>
<thead>
<tr>
<th>Instructor</th>
<th>Questionnaire</th>
<th>Test Statistic</th>
<th>P-value</th>
<th>Test Statistic</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al</td>
<td>1</td>
<td>2.1679</td>
<td>0.0223*</td>
<td>1.5553</td>
<td>0.0819</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>5.7265</td>
<td>0.0000**#</td>
<td>5.0789</td>
<td>0.0007**#</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>2.0192</td>
<td>0.0298*</td>
<td>4.0765</td>
<td>0.0024**#</td>
</tr>
<tr>
<td>Ben</td>
<td>1</td>
<td>-0.2721</td>
<td>0.6056</td>
<td>-0.7527</td>
<td>0.7619</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>2.6226</td>
<td>0.0089*</td>
<td>0.3652</td>
<td>0.3629</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>2.2349</td>
<td>0.0196*</td>
<td>0.2989</td>
<td>0.3868</td>
</tr>
<tr>
<td>Clyde</td>
<td>1</td>
<td>3.3384</td>
<td>0.0019*</td>
<td>-0.4936</td>
<td>0.6817</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>2.3337</td>
<td>0.0145*</td>
<td>3.4157</td>
<td>0.0056*</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>2.3123</td>
<td>0.0168*</td>
<td>0.8303</td>
<td>0.2169</td>
</tr>
<tr>
<td>Dan</td>
<td>1</td>
<td>4.0724</td>
<td>0.0004**#</td>
<td>2.8184</td>
<td>0.0129*</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1.6390</td>
<td>0.0598</td>
<td>-0.2251</td>
<td>0.5858</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>1.7318</td>
<td>0.0507</td>
<td>-0.3414</td>
<td>0.6286</td>
</tr>
<tr>
<td>Ellen</td>
<td>1</td>
<td>0.8234</td>
<td>0.2108</td>
<td>-1.8717</td>
<td>0.9483</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>2.2226</td>
<td>0.0200*</td>
<td>-0.5115</td>
<td>0.6876</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>0.8499</td>
<td>0.2036</td>
<td>-2.6371</td>
<td>0.9832</td>
</tr>
<tr>
<td>Fran</td>
<td>1</td>
<td>1.1244</td>
<td>0.1382</td>
<td>-1.5379</td>
<td>0.9160</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0.8075</td>
<td>0.2153</td>
<td>-1.4008</td>
<td>0.8980</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>1.1260</td>
<td>0.1379</td>
<td>-5.4260</td>
<td>0.9995</td>
</tr>
</tbody>
</table>
The asterisks (*) in Table 14 indicate where the p-values show that Hypothesis 5 is not rejected at $\alpha = 0.05$. The number signs (#) indicate where the p-values show that Hypothesis 5 is not rejected using the adjusted alpha levels. This indicates that student average responses and instructor responses tend to either decrease or increase together on the particular questionnaire indicated.

Upon examination of the results at $\alpha = 0.05$, where students' perceptions of collaborative learning are compared to instructors' perceptions of collaborative learning on subset 1 of the collaborative learning questionnaire, all questionnaires in Al's and Clyde's class tend toward a monotonically increasing relationship. The same is true for Questionnaire 2 of Ellen's class, Questionnaire 1 of Dan's class, and Questionnaires 2 and 3 of Ben's class. Recall that Questionnaire 1 was administered to both instructors and students before the start of the semester. P-values for Dan's Questionnaires 2 and 3 were extremely close to the alpha level under consideration. P-values for Questionnaire 2 of Al's class and Questionnaire 1 of Dan's class indicate that Hypothesis 5 cannot be rejected at $\alpha = 0.0013$. 
Upon examination of the results at $\alpha = 0.05$, where students' perceptions of their instructors' views of collaborative learning are compared to instructors' perceptions of collaborative learning on subset 2 of the collaborative learning questionnaire, only Al's Questionnaires 2 and 3, Dan's Questionnaire 1, and Clyde's Questionnaire 2 showed p-values to be less than $\alpha = 0.05$. Thus, in these four circumstances, there is evidence that Hypothesis 5 cannot be rejected. Results indicate that responses to these four questionnaires might show a monotonically increasing relationship at $\alpha = 0.05$. P-values for Questionnaires 2 and 3 of Al's class indicate that Hypothesis 5 cannot be rejected at $\alpha = 0.0028$.

Fran's class, on all six questionnaires, rejected the null hypothesis at all alpha levels of significance. This indicates that instructor responses and student responses did not tend to increase or decrease together. Test statistics were primarily negative for Ellen, Dan, and Fran on subset 2 of the questionnaire instrument (students' perceptions of instructors' views vs. instructors' perceptions).
Qualitative Analyses of Data

Research Questions 3 through 7 will be examined qualitatively in this section. Questions 3 to 5 were also quantitatively analyzed in the Statistical Analyses section. Qualitative data was collected via: (1) observation checklists, (2) instructor questionnaires, (3) student questionnaires, (4) instructor interviews, (5) student interviews, and (6) weekly logs. Refer to the four tables in Appendix J that contain information summarizing and comparing demographic, log, and observation data of the six calculus sections.

Recall that instructor names alphabetically correspond with the amount of time collaborative learning and lecture were used. Al instructed using a combination of least lecture and most collaborative learning (as compared to the other instructors). Al was followed by Ben, Clyde, Dan, Ellen, and Fran.

A summary of qualitative findings concludes this section.

Question 3

Do instructors' perceptions of collaborative learning change throughout the semester in the reform calculus course?
Hypothesis 3 was analyzed quantitatively. However, there are problems with using the Friedman test in this study when analyzing Hypothesis 3: (1) the Likert scores may not be continuous measures of instructors’ perceptions and (2) there is interaction between the section effect and questionnaire effect. Thus, this researcher performed a qualitative analysis of instructors’ perceptions changing over time in an attempt to answer Question 3.

This researcher examined instructor responses to the open-ended question on the collaborative learning questionnaire instrument, “Overall, what are your honest opinions of collaborative learning (small group work)?” Comments were qualitatively analyzed for positive, negative, or neutral meaning. Table 15 displays a summary of changes in perceptions of instructors and students during the semester.

It was found that Ellen tended to change her perceptions of collaborative learning from a slightly positive belief to a slightly negative one. At the beginning of the semester Ellen stated: “Groups work well when the students in that group have the same level of understanding of the material.” At the end of the semester Ellen
stated: “I don’t care for it. I felt like I spent more time wrangling personalities instead of teaching calculus.”

Table 15: Summary of (Number of) Instructor and Student End-of-Term Perceptions of Collaborative Learning

<table>
<thead>
<tr>
<th>Instructor</th>
<th>Gender</th>
<th>Positive</th>
<th>Negative</th>
<th>Neutral</th>
<th>No Change Over Time</th>
<th>Positive Change</th>
<th>Negative Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al</td>
<td>Male</td>
<td>11</td>
<td>0</td>
<td>2</td>
<td>11</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Ben</td>
<td>Male</td>
<td>10</td>
<td>2</td>
<td>5</td>
<td>8</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>2</td>
<td>1*</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>1*</td>
</tr>
<tr>
<td>Clyde</td>
<td>Male</td>
<td>20*</td>
<td>0</td>
<td>2</td>
<td>18*</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Dan</td>
<td>Male</td>
<td>2</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Ellen</td>
<td>Male</td>
<td>8*</td>
<td>5</td>
<td>4*</td>
<td>13*</td>
<td>0</td>
<td>4*</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>5</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Fran</td>
<td>Male</td>
<td>10*</td>
<td>6*</td>
<td>1</td>
<td>12*</td>
<td>1</td>
<td>4*</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>6</td>
<td>0</td>
<td>1</td>
<td>6</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

* One student is Asian

Clyde’s perceptions changed slightly from a more neutral stance to a more positive one. At the beginning of the semester Clyde stated: “I think there is too much stress on doing in-class group work. But, I believe working in groups can be wonderful.” At
the end of the semester Clyde stated: “I believe collaborative learning to be a valuable tool to be used in conjunction with lecture.”

Fran’s perceptions remained negative during the course of the semester. At the beginning of the semester Fran stated: “I really am not motivated at all to use it.” At the end of the semester Fran stated: “For an opening (beginning) class I think [collaborative learning] distracts rather than assists the students.”

Ben’s, Al’s, and Dan’s perceptions remained positive during the course of the semester. At midterm Ben stated: “Overall, I think collaborative learning is a plus.” At midterm Al stated: “I’m all for it!” At the beginning of the semester Dan stated: “[Collaborative learning] can be effective if [the students] are led properly.” At the end of the semester Dan stated: “It works very well if the students are rewarded for their efforts.”

**Question 4**

Do students’ perceptions of collaborative learning change throughout the semester in the reform calculus course?

Hypothesis 4 was analyzed quantitatively. There are problems with using the Friedman test in this study when analyzing
Hypothesis 4: (1) the Likert scores may not be continuous measures of students’ perceptions and (2) there is interaction between the section effect and questionnaire effect. Thus, this researcher performed a qualitative analysis of students’ perceptions changing over time in an attempt to answer Question 4.

Qualitative analysis of the results of Hypothesis 4 indicate that students’ perceptions became: (1) more negative on questions 1A, 12, and 13; (2) more positive on question 16; and (3) from positive, to negative, and back to positive on question 17. The data in Appendix K can be closely scrutinized to show this information. Charts in Appendix K display average responses of instructors and students to identical questionnaire items (1A to 28) on each of the three administered collaborative learning questionnaires.

Table 15 displays a qualitative summary of attitude changes in students during the course of the Fall semester, 1995. This researcher examined student responses to the open-ended question on the collaborative learning questionnaire instrument, “Overall, what are your honest opinions of collaborative learning (small group work)?” Comments were qualitatively analyzed for positive,
negative, or neutral meaning. Sample student comments are stated in the Question 5 section: **Student and Instructor Comments**.

Generally, students seemed positive about small group work in all classes, except Dan's section. In Dan's class, students seemed more negative or indifferent in their perceptions about small group work. Dan's class also had the most students whose perceptions changed negatively. Ben's class had the most students whose perceptions changed positively. All other classes contained students whose perceptions did not change much over time.

**Question 5**

Do students' perceptions of their instructors' views of collaborative learning reflect their instructors' stated perceptions?

Hypothesis 5 was analyzed quantitatively. Charts in Appendix K graphically display the differences (on each collaborative learning questionnaire) between instructor perceptions and average student perceptions. Table 15 displays a summary of student and instructor end-of-term perceptions of collaborative learning.
Student and instructor comments from collaborative learning questionnaires and interviews were examined in an attempt to answer Question 5.

Student and Instructor Comments

Three students from each section and all instructors participated in "fact-finding" interviews. These interviews gave this researcher information about the classroom settings and various perceptions held by the interviewing parties. Interview responses were also triangulated with questionnaire comment data, log data, and collaborative learning observation checklists. Comments from all student and instructor questionnaires were also analyzed. Tables 16 through 20 show summary information concerning responses to the five open-ended student questions on the collaborative learning questionnaire. Asterisks depicting what their respective instructors perceived about the topic are matched with these comments.

Table 16 displays a summary of the most common responses to question 1 on both the instructor and student collaborative learning questionnaires. Asterisks indicate that the instructor in that row also
gave such a response. Many of these positive features of small group work were also given during student and instructor interviews.

Table 16: Student Positive Features. (Percentages) of Small Group Work

<table>
<thead>
<tr>
<th>Instructor</th>
<th># of Comments</th>
<th>Diff points of View</th>
<th>Peer help</th>
<th>Social Skills/Teamwork</th>
<th>Gain Understand.</th>
<th>Opens Communication</th>
<th>Meet People</th>
<th>Discuss and Do Homework</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al</td>
<td>57</td>
<td>37*</td>
<td>35*</td>
<td>2*</td>
<td>5</td>
<td>4*</td>
<td>9*</td>
<td>5*</td>
<td>3</td>
</tr>
<tr>
<td>Ben</td>
<td>78</td>
<td>37*</td>
<td>22*</td>
<td>14*</td>
<td>6*</td>
<td>9</td>
<td>3</td>
<td>9*</td>
<td>0</td>
</tr>
<tr>
<td>Clyde</td>
<td>91</td>
<td>36</td>
<td>35*</td>
<td>7</td>
<td>11*</td>
<td>3*</td>
<td>2</td>
<td>4*</td>
<td>2</td>
</tr>
<tr>
<td>Dan</td>
<td>89</td>
<td>37</td>
<td>29*</td>
<td>6*</td>
<td>10*</td>
<td>4*</td>
<td>0</td>
<td>6*</td>
<td>8</td>
</tr>
<tr>
<td>Ellen</td>
<td>92</td>
<td>35*</td>
<td>17</td>
<td>10</td>
<td>9</td>
<td>8</td>
<td>5</td>
<td>12*</td>
<td>4</td>
</tr>
<tr>
<td>Fran</td>
<td>98</td>
<td>35</td>
<td>29*</td>
<td>11</td>
<td>12</td>
<td>7*</td>
<td>0</td>
<td>1*</td>
<td>5</td>
</tr>
</tbody>
</table>

* Instructors' stated perceptions

The second column in Table 16 indicates the number of comments students gave in answer to the question. Generally, students and instructors pointed out the "peer help" feature. One male student in Clyde's section explained this feature by saying that "students can help each other so that one person doesn't take up half the time having the instructor explain something." Another of Clyde's students (female) explains: "Often a fellow student can understand my question better, thus [he/she] can answer or explain it to me in terms I'll understand. [Also, we then have] study peers after class." This last comment was exactly what Clyde was striving
for in student group work. An “A” student (female) of Ellen’s put it this way:

You are forced to talk through your solution and break it down into steps that others can follow - this clarifies the concepts and helps you understand.

Thus, small group work that utilizes peer tutoring appears beneficial to all participants.

Students, as well as instructors, also value the variety of different points of view when solving problems. One of Al’s male students had the following comment on this subject: “It is a good chance to implement ideas and get an immediate response instead of wondering if you have the correct method of solving the problem.” A “B” student (male) in Ben’s class added: “It’s also like [giving] my knowledge back to the group - it makes me feel good.” An “A” student (female) in Fran’s class summed up the positive features in this way:

There are so many positive features of group work. One is that it helps people understand things better. Another is that it allows different ideas to be expressed, etc. Another is that group work allows the reinforcement of ideas brought up in lecture.

Collaborative learning also has many negative features. Table 17 displays a summary of the most common negative responses to
the utilization of small group work. One male student who began the semester in Ellen’s class and then switched to Dan’s class proclaimed:

“Group time is helpful but class time is better spent with instruction and feedback from the teacher. Group work should be encouraged on our own time in the help center. [Also] it wastes time that could be better spent with teacher instruction. If nobody in your group can answer a question, you need to refer to the teacher anyway.”

The latter student received a B on his comprehensive final examination.

Table 17: Student Negative Features (Percentages) of Small Group Work

<table>
<thead>
<tr>
<th>Instructor</th>
<th>Use Stud as Crutch</th>
<th>Lazy/Slacker/Nonpart</th>
<th>Slow/Time Consum.</th>
<th>Off Task</th>
<th>Peer Conflict</th>
<th>Not do/Share/Prep wk</th>
<th>Stud Behind or Ahead</th>
<th>Affects Grades</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al</td>
<td>27</td>
<td>18</td>
<td>15*</td>
<td>9</td>
<td>5</td>
<td>15</td>
<td>9</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Ben</td>
<td>12</td>
<td>12</td>
<td>11*</td>
<td>27</td>
<td>13</td>
<td>8</td>
<td>4</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>Clyde</td>
<td>18*</td>
<td>25</td>
<td>10*</td>
<td>15*</td>
<td>14</td>
<td>4</td>
<td>8</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Dan</td>
<td>15</td>
<td>17*</td>
<td>20</td>
<td>17*</td>
<td>13</td>
<td>5</td>
<td>7</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Ellen</td>
<td>13*</td>
<td>21*</td>
<td>9</td>
<td>5*</td>
<td>19*</td>
<td>18</td>
<td>6</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>Fran</td>
<td>21</td>
<td>12</td>
<td>19*</td>
<td>11*</td>
<td>9</td>
<td>7</td>
<td>9*</td>
<td>5</td>
<td>7</td>
</tr>
</tbody>
</table>

* Instructors’ stated perceptions

One female Asian student in Ben’s class had previously enjoyed small group work until she was placed in a “bad group.” She was able to obtain an A on her final examination, but commented that peer conflicts and bad group advice convinced her that small group work was not helpful. She is just one example where one or two negative
experiences can change a student’s attitude of small group work from positive to negative.

One of the interviewed male students in Ben’s class commented on another negative feature of small group work: “Groups become friends and sometimes want to talk about everything except math.”

Some students who are “ahead” of other students feel that small group work is too slow. A “B” student (male) in Fran’s class explained:

It is too time consuming. I have to wait for slow people to catch up and end up explaining the same thing ten times. I don’t like relying on others, nor do I like them relying on me. The time could be better spent having the instructor answer questions from homework.

One “A” student (male) who was interviewed from Clyde’s class commented that he did not like his grade to be “dependent, in any way, on other people - for better or for worse.” A female student in Ben’s class who is a proponent of group work discussed the drawbacks in this way:

Graded group assignments can be unfair when the whole group fails to participate. Also, extensive group work and little individual work diverts the individual from independent confidence.

Fran explained a negative feature from an instructor’s standpoint:

“Too much of a goal [of students in small group work] is on finishing
the problem rather than on comprehension. So, many people don't understand the whole problem.” Other instructors and students say that small group “discourages individual or independent thinking.”

Most students had some previous experience with small group work from their high school years. This could explain why many students maintained their initial perceptions at the end of the semester. Table 18 displays a summary of students’ previous small group work experiences in percentages.

<table>
<thead>
<tr>
<th>Instructor</th>
<th>High School</th>
<th>College</th>
<th>Little or None</th>
<th>Some</th>
<th>A Lot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al</td>
<td>36</td>
<td>4</td>
<td>15</td>
<td>36</td>
<td>9</td>
</tr>
<tr>
<td>Ben</td>
<td>38</td>
<td>7</td>
<td>10</td>
<td>34</td>
<td>10</td>
</tr>
<tr>
<td>Clyde</td>
<td>45</td>
<td>13</td>
<td>6</td>
<td>27</td>
<td>4</td>
</tr>
<tr>
<td>Dan</td>
<td>25</td>
<td>7</td>
<td>17</td>
<td>43</td>
<td>6</td>
</tr>
<tr>
<td>Ellen</td>
<td>33</td>
<td>16</td>
<td>11</td>
<td>32</td>
<td>8</td>
</tr>
<tr>
<td>Fran</td>
<td>34</td>
<td>4</td>
<td>9</td>
<td>41</td>
<td>10</td>
</tr>
</tbody>
</table>

Most of the qualitative analyses of the end-of-semester perceptions by students were taken from their responses to question 4 (Appendix D). Their comments reflected their honest opinions about small group work. Generally, students and instructors alike were completely candid in their remarks. Table 19 displays the
breakdown of students’ end-of-semester perceptions of small group work. Instructors were asked to perceive how their students felt about small group work. The asterisks indicate the instructor’s belief about their students’ viewpoints of small group work.

Table 19: Student Honest Opinions (Percentages) of Small Group Work

<table>
<thead>
<tr>
<th>Section</th>
<th>I Like It/It's Good/It works</th>
<th>I Don’t Like/Not Good/Not Work</th>
<th>Has Both Good and Bad Points</th>
<th>Don’t Know/Neutral</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al</td>
<td>85</td>
<td>0</td>
<td>11</td>
<td>4 #</td>
</tr>
<tr>
<td>Ben</td>
<td>59</td>
<td>20</td>
<td>17</td>
<td>3 #</td>
</tr>
<tr>
<td>Clyde</td>
<td>82</td>
<td>11</td>
<td>2</td>
<td>5 #</td>
</tr>
<tr>
<td>Dan</td>
<td>45</td>
<td>33*</td>
<td>19</td>
<td>3</td>
</tr>
<tr>
<td>Ellen</td>
<td>52</td>
<td>29*</td>
<td>15</td>
<td>3</td>
</tr>
<tr>
<td>Fran</td>
<td>67</td>
<td>26*</td>
<td>6</td>
<td>1</td>
</tr>
</tbody>
</table>

* Instructors’ final views on how they perceive their students to view small group work
# Commented that it varies from student to student or group to group.

Several honest opinions were expressed by the students. Here are just a few of the unique comments that were offered:

A “C” student (female) in Ellen’s class commented: “To be honest, I didn’t dislike group work as much as I thought I would. However, I didn’t find it noticeably beneficial either.”

An “A” student (female) in Al’s class said: “It’s very helpful when you are with people who are willing to do their best.”

A female student in Fran’s class commented: “I think
everyone, even someone who doesn’t have any trouble with the material, can benefit from group work.”

A “C” student (male) in Clyde’s class stated: “It helps students to understand things better because they might miss something the instructor says or they might not get it.”

Lastly:

an “A” student in Ben’s class said: “I enjoy it and believe that it benefits me. I don’t think it should be stressed over individual learning, but it is a useful tool in education.”

Al’s and Clyde’s classes seemed to have the most positive perceptions of small group work. Dan’s, Ellen’s, and Fran’s classes were more negative than the other classes.

Students were also given the opportunity to state how they perceived their instructor to view small group work. In Table 20, student percentages are calculated by class and the asterisks indicate the actual beliefs of the instructors.

Students’ perceptions were consistent with instructors’ perceptions in the cases of Al, Ben, and Clyde. Students were apparently “fooled” by Fran. Dan’s class did not know what to think about Dan’s perceptions of small group work. And, even though Ellen expressed negative perceptions of small group work, her students did not perceive this to be her attitude.
Table 20: Students' Perceptions (Percentages) of How Their Instructor Views Small Group Work

<table>
<thead>
<tr>
<th>Section</th>
<th>Favors/Likes GW the Way Instructor Sets It Up</th>
<th>Not Favor/Dislike the Way Instructor Has It Set Up</th>
<th>Don't Know/Neutral</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al</td>
<td>72*</td>
<td>0</td>
<td>28</td>
</tr>
<tr>
<td>Ben</td>
<td>61*</td>
<td>6</td>
<td>33</td>
</tr>
<tr>
<td>Clyde</td>
<td>69*</td>
<td>4</td>
<td>27</td>
</tr>
<tr>
<td>Dan</td>
<td>24*</td>
<td>22</td>
<td>54</td>
</tr>
<tr>
<td>Ellen</td>
<td>45</td>
<td>2*</td>
<td>53</td>
</tr>
<tr>
<td>Fran</td>
<td>67</td>
<td>5*</td>
<td>28</td>
</tr>
</tbody>
</table>

* Instructor's Honest Opinion of small group work

Question 6

Are instructors' perceptions of collaborative learning reflected in their actual teaching practice?

The collaborative learning observation checklist in Appendix B was used to gather data on instructors' actual teaching practice. The results and summaries of each instructor's nine observations are discussed in the individual class profiles in this chapter and reflected in the four tables in Appendix J. Data gathered from the final instructor collaborative learning questionnaire and the instructor interview instrument were used to qualitatively analyze Question 6.
Al’s faith in small group work and positive perception of this instructional idea was very evident to his students and this researcher. He purposefully assigned lengthy small group work assignments to foster outside group work and enable students to think, share ideas, tutor one another, and produce better quality work. Thus, he did not perceive small group work to be slow. He believed that facilitating small group work must be learned in order to adequately implement and use it. Al added structure to his course to assist his students in learning about collaborative learning.

Al indicated in questionnaires and the interview that he believes in a good balance of lecture and small group work. This was demonstrated in his course. He also believed that both individual work and small group work are important. Students sometimes worked independently in their groups and shared solutions and strategies. Al firmly believed in the collaborative learning instructional strategy.
Ben believed that students working in small groups could discuss more complex problems, "think reflectively," and obtain different students' ideas on calculus concepts. Ben used small groups to discuss "large-scale" concepts vital to the understanding of calculus. Ben believed that: (1) group work could be slow, (2) students could get off-task, and (3) students could be too dependent on one another for assistance. Ben's class depicted these viewpoints. Ben did not tie individual grades to small group work because he disapproved of this grading technique. He never used group-graded assignments. He liked to see peers tutoring peers. Peer tutoring was evident in his classroom. Ben also liked to use a balance of group work and lecture.

Ben believed that collaborative learning: (1) is hard to implement, (2) must be learned, (3) must be taught to students, and (4) could be better used with practice. Ben took the time at the beginning of the semester to prepare his students and himself for small group work.

Ben's comments on the interview and collaborative learning questionnaires were highly consistent with his classroom routine,
management, and actions. He often joked with his class in order to create an enjoyable atmosphere. However, he did comment that "their enjoyment is not necessary for there to be benefits."

Clyde

During the beginning of the semester, Clyde encouraged more student involvement in small group work than he did at the end of the semester. He was tired of "baby-sitting" the students and wanted them to take more individual responsibility for their learning in reform calculus. Thus, he did not want to teach them how to work in small groups, nor did he believe that implementation of small groups must be learned. Clyde did like the voluntary participation of his students in small group work and he liked to see peers tutoring peers and students extending their small work groups outside of class. He believed group work was hard to implement, yet he believed collaborative learning was an appropriate instructional strategy that allowed the communication between students.

Since Clyde did not like to see off-task and unproductive small groups, he conveyed to his class that students should come to class on small group days only if they were serious about helping each
other learn calculus. Students were generally positive about small group work in Clyde’s class. Clyde believed in collaborative learning, but wanted productive and beneficial small group work to occur.

Clyde’s perceptions of small group work were primarily positive and he expressed these opinions to his students. He knew the negative and positive features of small group work and tried to implement collaborative learning in ways that benefited his students the most.

Dan

Dan believed that students could work through more complex problems in groups, but did not always assign such problems. His students usually worked in small groups to review for tests and quizzes. Dan seemed positive about small group work as indicated by: (1) questionnaires, (2) the interview, and (3) conversations with this researcher. However, his classroom demeanor did not always advocate or encourage a collaborative learning atmosphere. Sometimes Dan’s stated perceptions contradicted his classroom practices. For instance, Dan disliked letting students work on homework during small group time, but his students inevitably did
this. Also, Dan indicated on the questionnaire that he disapproved of student absenteeism during small group work. However, Dan never related these feelings in the classroom. Dan agreed that implementing group work must be learned. Dan did like watching peers tutoring peers, but did not like students’ individual grades tied to small group work.

Dan preferred the lecture method of teaching as opposed to small group work. Interviewed students from his class agreed with this finding. Dan tried to implement small group work in his classroom as best as he could given his inexperience with collaborative learning.

**Ellen**

Ellen liked to assign more difficult or complex problems to her students and this was depicted in class and from her comments. Also, she did not believe in “rewarding” students. She stated that students do not produce better quality work during collaborative learning. However, she required graded group assignments. Even though Ellen liked to see: (1) peers tutoring peers, (2) students
actively contributing ideas, and (3) productive work groups, she still preferred the lecture method over small group work.

Ellen spent many hours deciding how to implement and manage small groups and believed that this instructional strategy had to be: (1) learned by instructors, (2) taught to students, and (3) practiced by everyone to ensure proper implementation. However, she did not enjoy teaching students to communicate and collaborate in small group settings. Ellen also believed group work was slow.

Ellen’s written comments were sometimes more positive than her verbal comments to this researcher or in her actions during class. Ellen was discouraged with group work and did not like it. This was sometimes, but not usually, evident in her teaching.

Fran

Despite Fran’s disapproval of collaborative learning, she indicated during class that student small group work was required and important. Her students were generally positive about collaborative learning and they thought their instructor was positive about small group work. Fran believed that small groups: (1) could discuss more complex problems, (2) could discuss different ideas
when working on problems, and (3) would work more effectively when rewarded. Fran also believed that: (1) group work was slow, (2) lecturing was better than small group work, and (3) the collaborative learning strategy had to be learned. She did not believe that collaborative learning helped her students to better learn the calculus concepts. She believed that students relied on each other for small group grades.

Fran subtly indicated her negative perceptions of collaborative learning during the course. She acted disinterested in collaborative learning by: (1) grading homework papers, (2) reading papers or books, and (3) working on her own assignments, during small group work. She also left the room while students worked in small groups.

When Fran was available, she assisted students in working in small groups and encouraged student participation during collaborative learning. She also answered student questions with questions to spark student collaboration.

Question 7

Do instructors feel that the collaborative learning workshop met their needs?
An analysis of the open-ended responses from the instructor interview will be performed qualitatively in an attempt to answer Question 7.

Two collaborative learning workshop questions were asked of the graduate teaching assistants (GTA) on a midterm interview. They were:

1. During the GTA collaborative learning workshop, what best helped prepare you to use collaborative learning in your class?

2. What else could have been discussed in the GTA collaborative learning workshop that would have helped prepare you in using collaborative learning in your class?

Ben commented that there was nothing discussed at the workshop that best helped prepare him to use collaborative learning. He attended the workshop with preconceptions of what would be troublesome for small groups - instructors "just walking in and expecting [the students] to get into groups and start working." Ben did not want leaders in small groups, but rather collaborators within small groups. Ben said that the workshop was good for introducing the textbook problems and the philosophy of the reform calculus course.
Clyde and Ben stated that learning ways about how to form small groups was helpful. Ellen commented that it was helpful to discuss issues with experienced calculus instructors. She profited from their perspectives on how they formed groups, taught the Harvard calculus, and covered the material. Even though Dan did not attend the workshop, he found it helpful to discuss instructional strategies with previous calculus instructors. Al, Ben, and Clyde found that discussing instructional strategies amongst themselves was helpful when implementing collaborative learning in reform calculus.

Al profited from the workshop by learning about collaborative learning. He learned about instructors' various collaborative learning strategies and then he obtained more information about collaborative learning from the library. Al appreciated experienced instructors' viewpoints on collaborative learning. He said that it was an opportunity for him to socialize and share ideas with other calculus instructors. Al also said that it was important for him to learn about students' expectations of small group work and what collaborative learning methods had previously been used. Fran did not learn anything that helped prepare her for using collaborative learning in
the calculus classroom. Fran profited from talking to other calculus instructors about collaborative learning - especially her father.

All instructors believed that the workshop was too long and repetitive. Ben believed that it would be more beneficial to conduct the workshop several days before the beginning of classes. He stated that instructors would then have the opportunity to reflect on what they had discussed in the workshop.

Clyde and Ellen believed that workshop facilitators should give instructors a list of previous calculus instructors to contact as resources. Ellen would like experienced instructors to discuss their collaborative learning strategies at the workshop. She would like to know how they managed large class sizes and what small group strategies worked in their calculus classes. Dan would like to know how experienced instructors formed groups and managed small group work. He would also like to see examples of small group projects that could be assigned to students.

Ben commented that workshop participants should be taught how to deal with group dynamics. He believed that reform calculus instructors should model the Harvard philosophy as they instruct
first semester engineering calculus. Al did not have any recommendations for improving the workshop.

Summary of Qualitative Results

This section, consisting of two components, summarizes the qualitative results discussed in Chapter 3. They are: (1) Instructor Behavior Patterns and (2) Instructor and Student Perceptions.

The patterns section contains eight instructional traits that emerged from the qualitative data. These patterns reflect factors common to the collaborative learning model recommended by reform calculus authors. The perceptions section summarizes the instructors' and students' perceptions that emerged from the qualitative data.

Instructor Behavior Patterns

Enjoyment of Collaborative Learning and Teaching

Instructors who enjoy teaching and using collaborative learning often indicate to their students their attitudes regarding collaborative learning. These instructor attitudes can often be detected by their students during instruction. Reform calculus
emphasizes strategies that include more student-centered learning. Instructors who enjoy teaching using collaborative learning and indicate these attitudes to their students are likely to be effective reform calculus instructors.

Three of the four male instructors in the study stated that they enjoyed using collaborative learning while teaching calculus. They were positive about collaborative learning before, during, and after teaching the reform calculus course. One of these male instructors specifically requested the first semester engineering calculus teaching assignment and shared this fact with his students. The fourth male instructor changed his perceptions about collaborative learning from neutral to positive during the course. Both female instructors had negative perceptions after being required to use collaborative learning during the course.

The female instructor who intends to pursue a career in industry changed her perceptions of collaborative learning from positive to negative. However, she effectively implemented collaborative learning as did all other instructors. The other female instructor remained negative about collaborative learning throughout the reform calculus course.
Three of the four male instructors who enjoyed using collaborative learning planned to use small group work in their classrooms following the completion of their degrees. The other three instructors (two females, one male) were uncertain or indifferent about using collaborative learning in the future.

Emphasis on the Importance of Student Attendance

Student attendance in reform calculus is important, especially during collaborative learning. During small group work, students are able to discuss issues, solve problems, and attempt to reach individual or group conclusions with peers of similar abilities. Instructors can emphasize the importance of student attendance through their instructional behaviors. Instructors who stress the importance of student attendance are, in part, emphasizing the importance of collaborative learning in reform calculus.

Students were encouraged to attend class during lecture and small group work. Instructors emphasized the importance of student attendance in various ways. Two male instructors verbally emphasized the importance of student attendance during collaborative learning in the beginning sessions of the semester. One
female instructor collected and graded weekly collaborative learning assignments and used a question-of-the-day to encourage attendance. During the middle of the semester, two other instructors (one female, one male) introduced cover sheets in order to monitor student attendance during collaborative learning. One male instructor who did not emphasize the importance of student attendance facilitated weekly small group sessions that were unstructured and, at times, chaotic.

**Clear Student Expectations**

Reform calculus emphasizes graphical, numerical, and algebraic representations of the calculus ideas. Traditional calculus instruction had depended on algebraic processes and seldom emphasized the graphical and numerical processes. Thus, reform calculus students are expected to think and learn in these three ways. Reform calculus textbook problems are to be solved using these three processes.

Instructors who teach reform calculus must model these representations during instruction. Instructors must also clearly define the reform calculus goals, objectives, and expectations for student work. Two of the three male instructors intending to use
collaborative learning in the future clearly specified student expectations for writing solutions to homework problems. They used overheads to model "good" write-ups. The other male instructor planning to use collaborative learning in the future incorporated the use of cover sheets to assist the students in attaining the desired expectations. The female instructor intending to go into industry also used cover sheets. The other two instructors (one female, one male) did nothing special to assure that the goals, objectives, and expectations for student group work were met.

**Definitely Stated Collaborative Learning Objectives and Directions**

An effective collaborative learning strategy must have clearly defined objectives, directions, and student expectations. Instructors and students need to be aware of the benefits of the collaborative learning assignments. Students need to be aware of the expectations for small group work. Thus, instructors must clearly state assignment objectives and directions.

The instructors in this study clarified objectives and directions for collaborative learning assignments in various ways. Two instructors incorporated the use of cover sheets to assist the students
in understanding the objectives, directions, and expectations of small group work. These two instructors also verbally explained collaborative learning objectives and expectations. Five of the instructors (one female, four males) verbally explained small group work objectives and directions. One female instructor wrote the directions or expectations on the chalkboard without discussion.

**Balance of Lecture and Collaborative Learning**

Reform calculus emphasizes various instructional strategies such as student-centered learning, interactive lectures, student presentations, and technological demonstrations. Instructors have different teaching styles and students have different learning styles. Instructors who teach calculus using only one instructional strategy may be neglecting the learning styles of many of their students. Instructors who use a balance of instructional strategies may be assisting more of their students in learning the calculus concepts.

All graduate teaching assistants in the study were encouraged to use collaborative learning and lecture. The instructors used varying amounts of these two basic instructional strategies. The male instructor who used the most collaborative learning did so for
38 minutes (250 minutes total per week) more per week than the female instructor who used the least amount of collaborative learning. All of the instructors used a balance of lecture and collaborative learning. Three of the four male instructors also used test reviews during the course.

**Active Lecturing**

A component common to the major reforms is instructing interactively. This involves instructors facilitating student learning by questioning students and promoting class discussions (Hughes-Hallet et al., 1994b). Three instructors (one female, two males) were identified by this researcher as active lecturers (instructing interactively). The most active lecturer of all instructors in the study was a female instructor who had negative perceptions of collaborative learning. She did not believe students benefited from the use of collaborative learning, although she consistently implemented collaborative learning. However, her students were active participants during small group work and lecture.

Three instructors (one female, two males) were identified as passive lecturers. They were more directive when lecturing and
answering student questions. One of these instructors (female) lectured more than the other instructors. The two female instructors lectured the most and utilized collaborative learning the least as compared to the other instructors. These two females had negative perceptions of collaborative learning at the end of the semester.

**Answering Student Questions With Questions**

The National Council of Teachers of Mathematics (1989) emphasizes that instructors should teach in ways that assist students in becoming real-life problem solvers. Students need to learn how to make decisions, communicate mathematically, self-reflect, reason mathematically, and make connections. Instructors who question students’ responses and conclusions can help their students reflect, communicate, and reason mathematically.

The female instructor who was the most active lecturer asked her students if any group member knew the solution to a problem before she attempted to assist them. She questioned her students’ questions, responses, and conclusions during lecture and small group work. Two male instructors responded to their students in directive
ways. They seldom answered student questions with questions. They usually offered the students much assistance.

Three instructors (one female, two males) maintained eye contact with small groups when addressing student questions. Eye contact is an important factor when addressing student questions. Instructors who maintain eye contact with students can show their students that students’ questions and responses are important. Eye contact was not evident for the three passive instructors.

**Emphasis on Concept Understanding Varied Widely Between Instructors**

The underlying reason for the reform calculus movement is to assist students in understanding the calculus concepts as opposed to helping students in learning the mechanics during calculus problem solving. Many students in traditional 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, 1993). Instructors can use collaborative learning as an alternative strategy to lecture in helping students understand the concepts.
The instructors in the study implemented various small group work strategies to assist their students in understanding the calculus concepts. One male instructor asked his students to discuss a few "large-scale" concepts during collaborative learning. One female instructor required her students to solve two or three textbook problems during collaborative learning. These instructors' students concentrated on a few calculus concepts during small group work.

The four other instructors asked students to discuss many concepts during collaborative learning. Two male instructors expected their students to work on assigned homework problems during small group work. One female instructor assigned several complex small group problems that involved many calculus concepts. Another male instructor assigned approximately ten weekly small group problems to promote group work outside the classroom. These instructors apparently did not understand or agree with the "less is more" approach advocated in the calculus reform recommendations (MAA, 1986;1993).
Instructor and Student Perceptions

Instructor Perceptions of Collaborative Learning

This study found that instructors’ perceptions of collaborative learning do not relate to students’ final examination scores. However, instructors’ perceptions of collaborative learning do relate to their instructional practices and their students’ end-of-semester perceptions of collaborative learning. Three male instructors: (1) were positive about collaborative learning, (2) maintained positive collaborative learning behaviors, and (3) taught students who were positive about collaborative learning. The other male instructor: (1) was positive about collaborative learning, (2) maintained neutral or negative collaborative learning behaviors, and (3) taught students who were neutral or negative about collaborative learning. The female instructors: (1) were negative about collaborative learning, (2) maintained neutral or positive collaborative learning behaviors, and (3) taught students who were neutral or positive about collaborative learning. This suggests that instructors’ collaborative learning behaviors do relate to their students’ perceptions of collaborative learning.
During the course of the semester: (1) one female instructor changed her perceptions of collaborative learning from a slightly positive belief to a slightly negative one; (2) one male instructor’s perceptions changed slightly from neutral to positive, (3) three male instructors’ perceptions remained positive during the course of the semester, and (4) one female instructor’s perceptions remained negative during the course of the semester.

The female instructor whose perceptions changed from positive to negative was frustrated with collaborative learning. To her credit, she changed instructional strategies three times during the semester in an attempt to improve the effectiveness of collaborative learning in her classroom. The other female instructor who indicated negative perceptions of collaborative learning reflected these perceptions during instruction in subtle ways (e.g. instructor leaving class during small group work). However, the questionnaire responses of her students indicated their belief that she supported collaborative learning.
Student Perceptions of Collaborative Learning

This study found that students' perceptions of their instructors' views of collaborative learning were related to instructors' consistent implementation of collaborative learning. Students were generally positive about small group work except in one male instructor's section. This instructor made positive statements about collaborative learning, but taught in ways inconsistent with his beliefs and had students who had negative or indifferent perceptions about small group work. His students' perceptions changed from positive to negative or neutral during the semester.

One male instructor taught many students whose perceptions changed from negative or neutral to positive. This instructor was positive about collaborative learning and taught in ways consistent with his beliefs.

In the other four sections, students did not change perceptions during the semester. The students' positive perceptions of collaborative learning were consistent with their instructors' teaching practices.
Instructors' Perceptions of the Collaborative Learning Workshop

When asked in an interview during the semester, all the instructors recommended the collaborative learning workshop to inexperienced instructors new to the goals of reform calculus. The instructors stated that the workshop was useful for introducing the Harvard philosophy, goals, and textbook problems. However, all the instructors recommended that the workshop be shorter in length and not as repetitive.

The instructors stated that they profited from listening to experienced reform calculus instructors discussing their collaborative learning techniques during and following the workshop. Furthermore, they stated that this assisted them in adopting collaborative learning strategies in their own classes.
SUMMARY, CONCLUSIONS, DISCUSSION, AND RECOMMENDATIONS

Introduction

Calculus reform 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. 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. Therefore, 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 collaborative classroom learning techniques actually assist students in learning the calculus concepts. Also, the calculus instructors in this study (i.e. graduate
teaching assistants) have a variety of perceptions concerning collaborative learning. Identifying these differences of opinion about collaborative learning and determining the relationships between the instructor's view of collaborative learning and their students' achievement are important to the mathematics education community. The purpose of this study was to determine the perceptions of graduate teaching assistants and their students on collaborative learning in reform calculus and its relationship to instruction and achievement.

Summary

The course taught by the instructors participating in this study was Calculus and Analytic Geometry I (first semester engineering calculus), a reform calculus class that utilized instructional strategies recommended as calculus reform strategies. The strategy investigated in this study was collaborative learning. The study defined collaborative learning as students working in small groups, solving problems, discussing issues, and attempting to reach individual or group conclusions (Slavin et al., 1985).
Six graduate teaching assistants with his/her respective class of students were treated as independent case studies. The study occurred during the entire Fall semester, 1995, at MSU-Bozeman. Instructors were observed, surveyed, and interviewed to gather information on their perceptions of collaborative learning and their instructional approaches to the implementation of small group work. Students were observed, surveyed, and interviewed to gather information on their perceptions of collaborative learning.

The study also attempted to determine if the two-day workshop training provided just prior to the beginning of the semester for calculus graduate teaching assistants, was sufficient to influence the instructors and students regarding collaborative learning. All instructors at the end of the semester believed that the workshop was useful for introducing the Harvard textbook, calculus reform philosophy, and instructional expectations. However, instructors suggested ways to improve the workshop, such as shorter workshop hours and including more experienced first semester engineering calculus instructors who had used small group work.

The problem of this study was to determine the separate and collective contributions of: (1) the calculus section effect (the effect
of the 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' individual teaching practices utilizing collaborative learning was also examined and related to instructors' and students' perceptions.

Quantitative research methods were used to answer five of the research questions in the study:

1. How do each of the three 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?

The five statistical null hypotheses derived from these research questions were as follows:

1. There is no statistically significant relationship between the dependent variable (student achievement on a comprehensive final examination) and the collective contribution of the independent variables (the calculus section effect, students' perceptions of collaborative learning, and students' perceptions of their instructors' views of collaborative learning).
2. There is no statistically significant relationship between the dependent variable (student achievement on a comprehensive final examination) and the separate contribution of the independent variables (the calculus section effect, students' perceptions of collaborative learning, and students' perceptions of their instructors' views of collaborative learning).

3. There is no statistically significant change in instructors' perceptions of collaborative learning throughout the semester in the reform calculus course.

4. There is no statistically significant change in students' perceptions of collaborative learning throughout the semester in the reform calculus course.

5. There is no statistically significant difference (for each instructor) between students' perceptions of their instructors' views of collaborative learning and their instructors' stated perceptions.

Hypothesis 1 was rejected at the $\alpha = 0.05$ level of significance.

The statistical procedure used showed that 17% of student final examination score variability is explained when clustering the
questionnaire data (students’ perceptions of collaborative learning, students’ perceptions of their instructors’ views of collaborative learning) and the calculus section effect. Hypothesis 2 was not rejected when using calculus section effect as the independent variable. Hypothesis 2 was rejected when using students’ perceptions of collaborative learning and students’ perceptions of their instructors’ views of collaborative learning as the independent variables. Hypotheses 3 and 4 were not rejected at the $\alpha = 0.05$ level of significance. For Hypothesis 5, each of the instructors was separately analyzed. Hypothesis 5 was rejected for five of the six instructors.

Qualitative research methods were used to address five of the research questions in this study. Note that the first three questions below were also addressed through quantitative analyses.

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?

The summary section of the Qualitative Analyses in Chapter 3 summarizes the findings relating to these five research questions. This section also showed the nature and extent of implementation of collaborative learning in each classroom.

This chapter also conceptualizes results from the study which show how calculus instructors might be better informed of the goals of reform calculus and how they might be better trained and prepared to successfully teach to the reform calculus goals.

Conclusions and Discussion

The results from the quantitative analyses showed that 17% of student final examination score variability is explained by the collective contribution of students’ perceptions of collaborative learning, students’ perceptions of their instructors’ views of collaborative learning, and the students’ calculus section in which
they were enrolled. Seven questionnaire items, of the 29 total items, and the students' calculus section in which they were enrolled accounted for this variability. Four of the seven questionnaire items pertained to students' own perceptions of collaborative learning and three questionnaire items pertained to students' perceptions of their instructors' views of collaborative learning. Note that there were no statistical differences *between sections* on students' perceptions of collaborative learning and their instructors' views of collaborative learning as measured by the seven questionnaire items.

The students' section in which they were enrolled (when analyzed separately) did not contribute to students' final examination score variability. When analyzed separately, students' perceptions of collaborative learning, as measured by three clustered questionnaire items (of the 20 items relating to students' own perceptions of collaborative learning), negatively correlated (-24%) with students' final examination scores. A negative correlation was found between students' scores on the comprehensive final examination and students' perceptions on three questionnaire items: (1) I produce better quality work when working in small groups, (2) I like lots of group time, and (3) I like my individual grade tied to
group work. Students’ overall perceptions of collaborative learning cannot be generalized from these three questionnaire items.

When analyzed separately, students’ perceptions of their instructors’ views of collaborative learning, as measured by three questionnaire items (of the nine items relating to students’ perceptions of their instructors’ views of collaborative learning), positively correlated with students’ final examination scores. A 20% correlation was found between students’ scores on the comprehensive final examination and students’ perceptions of their students’ views of collaborative learning on two questionnaire items: (1) My instructor uses a good balance of group work and lecture and (2) My instructor feels that it is important to teach students how to communicate. A 19% correlation was found between students’ scores on the comprehensive final examination and students’ perceptions of their instructors’ views of collaborative learning on the questionnaire item: My instructor feels that class members do not rely too heavily on their peers during group work. Students’ overall perceptions of their instructors’ views of collaborative learning cannot be generalized from these three questionnaire items.
According to the results for closed response questionnaire items, instructors and students entering first semester engineering calculus have perceptions of collaborative learning that do not significantly change throughout the semester. However, the interview and open-ended questionnaire items for one female instructor showed that she had a positive to negative change in perceptions of collaborative learning. Furthermore, results for open-ended questionnaire items showed that students in two sections of first semester engineering calculus changed their perceptions. In one section, the change was from negative or neutral to positive, and in the other section, the change was from positive to negative or neutral. These differing results from the quantitative and qualitative data indicate the importance of gathering different types of data to more fully understand participants’ perceptions.

Students’ perceptions of their instructors’ views of collaborative learning do not necessarily reflect their instructors’ perceptions of collaborative learning. For five of the six instructor cases, students’ perceptions of their instructors’ views of collaborative learning were independent of their instructors’ perceptions of collaborative learning.
Thompson's study (1984) found that there exists a complex relationship between instructors' beliefs and practice. This researcher has found evidence consistent with this conclusion. One male instructor was positive about collaborative learning and this was not reflected in his teaching practice. His classroom behaviors reflected an indifferent or negative perception of small group work. A female instructor had negative perceptions of small group work. She followed her supervisor's suggestion by including one day of small group work per week. Her students expected small group work and were positive about collaborative learning.

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). This researcher has found mixed data relating to this statement. Three male instructors had positive perceptions of collaborative learning. Their teaching practices were consistent with their positive perceptions. The two female instructors were negative about collaborative learning and these views were subtly reflected in their teaching practices.
However, their students had positive perceptions of collaborative learning.

Participants in this study did have specific perceptions of collaborative learning. This conclusion is consistent with Brody and Hill (1991). Students and instructors had preconceived beliefs about collaborative learning according to this study’s findings. Most students and instructors did not change their perceptions of collaborative learning during the semester. This would indicate that students and instructors have preconceived ideas of collaborative learning prior to the first semester engineering calculus course. This researcher recommends that future researchers directly question instructors and students about how their perceptions of collaborative learning have changed during the semester.

One male instructor, who had positive perceptions of collaborative learning, taught many students who changed their perceptions from negative or neutral to positive. His positive perception of collaborative learning was reflected during classroom instruction. He was comfortable using collaborative learning and this influenced his students perceptions.
As instructors use collaborative learning in their classrooms for the first time and encounter student reactions to the instructional strategy their perceptions concerning the nature of collaborative learning can change. Collier (1972), Marks (1990), and Thompson (1984) determined that a teacher’s change in perceptions of mathematics and mathematics teaching occur due to their own teaching experiences and past learning experiences. This was observed in one female instructor’s class. Her frustrating experiences with collaborative learning (e.g. students failing to finish small group problems during the allotted time, students asking more questions than she expected) impacted her perceptions. She changed her perceptions from positive to negative during the course of the semester.

Instructors in this study who were required to use collaborative learning (regardless of their perceptions about collaborative learning) were, to some degree, effective small group facilitators. Instructors who were effective small group work facilitators practiced several of the collaborative learning behaviors recommended by reform calculus authors: (1) enjoyment of using collaborative learning and teaching, (2) emphasizing the importance
of student attendance during collaborative learning, (3) clearly indicating student expectations, (4) definitely stating small group work objectives and directions, (5) using a balance of lecture and collaborative learning, (6) lecturing actively, (7) answering student questions with questions, and (8) emphasizing student understanding of the calculus concepts.

The use of workshops can be helpful in informing instructors about collaborative learning. However, instructors also need a strong support system of peers who have previously used collaborative learning. Graduate teaching assistants that have not previously taught using collaborative learning need to and want to discuss: (1) issues about calculus reform, (2) strategies used to implement collaborative learning, and (3) calculus reform problems, with experienced collaborative learning instructors.

Several general conclusions have been determined as a result of this study:

(1) When instructors are required to teach calculus using collaborative learning, the calculus section in which a student is enrolled does not significantly affect students' final examination scores.
(2) Most graduate teaching assistants (five of the six instructors) did not change their original perceptions of collaborative learning during the semester.

(3) Students have preconceived ideas of collaborative learning that seldom change during the semester.

(4) Very few students change their perceptions of collaborative learning during the semester unless instructors' behaviors lead students to believe that their instructor has a strong bias (either positive or negative) toward collaborative learning.

(5) Graduate teaching assistants' classroom behaviors influence students' perceptions of collaborative learning.

(6) The instructors in this study were required to teach using collaborative learning, and were relatively effective at implementing this approach. The degree of effectiveness varied from instructor to instructor.

(7) The instructors in this study were required to use collaborative learning, and adjusted their teaching practices in an attempt to successfully implement collaborative learning and increase student understanding of the calculus concepts.

(8) Instructors teach reform calculus using a variety of
collaborative learning strategies. When instructors use collaborative learning for the first time, the model they implement may not be as complete as the reform model. Instructors' practices might more closely match the reform model with more experience.

(9) Requiring graduate teaching assistants to teach using collaborative learning, even when accompanied by only modest professional development support (as in this study), appears to help instructors teach in some of the ways consistent with an effective collaborative learning model.

Recommendations

The following is a list of recommendations for the implementation of collaborative learning in a reform calculus course. The list considers instructors' perceptions of collaborative learning, students' perceptions of collaborative learning, and instructors' actual teaching practice:

(1) Interview prospective instructors to determine if their perceptions of collaborative learning are consistent with the goals of reform calculus. Use the stated perceptions as
diagnostic information for determining an appropriate plan for professional development.

(2) Continue to educate and train instructors in the implementation of collaborative learning in reform calculus during the semester. A two-day workshop does help train the instructors. However, a support system of instructors who have previously taught calculus using collaborative learning is what calculus instructors believe they need. This support system can be implemented by requiring the instructors teaching first semester engineering calculus to meet once or twice a week for one hour with instructors experienced in using collaborative learning.

(3) Educate prospective reform calculus instructors to monitor students' responses to collaborative learning and to adjust their instructional approaches accordingly. As instructors and their students become accustomed to collaborative learning, it is important for the instructors to remain observant and flexible.

(4) Provide resources such as experienced reform calculus instructors to discuss and reflect on collaborative learning instructional strategies with the first time reform calculus
instructors during the workshop and while the course is taught.

(5) Encourage instructor reflection on their collaborative learning perceptions and teaching practices by having weekly meetings and discussions where instructors share what is happening in their classes, with special emphasis on the complex strategies associated with reform calculus.

(6) Facilitate on-going modeling of collaborative learning by experienced instructors. Reform calculus supervisors can demonstrate appropriate collaborative learning models for first time instructors teaching reform calculus.

(7) Encourage peer coaching pairs. Provide first time instructors with an experienced mentor instructor.

Recommendations for Future Research

Complex relationships exist between students' and instructors' perceptions of collaborative learning and students' and instructors' behaviors in reform calculus. These relationships are subtle and difficult to identify. More studies need to be performed examining these intricate subtleties.
Females participating in this study performed relatively well on the comprehensive final examination (See Tables 5 and 6). These students were generally positive about collaborative learning. More studies need to be performed which relate to gender, ethnicity, and collaborative learning in the reform calculus classroom. In this study, there were too few students of ethnic backgrounds different than Caucasian to make any general conclusions.

More studies need to be performed which examine various models for educating and training graduate teaching assistants in the implementation of collaborative learning. This study examined the two-day intensive workshop as one way of educating instructors. Other approaches like supervisor modeling or immersion can be effective in training instructors to successfully use collaborative learning in the calculus classroom. Additional studies also need to be performed that examine different collaborative learning training programs consistent with the goals of reform calculus.
References Cited


Collier, C. P. (1972). Prospective elementary teachers' intensity and ambivalence of beliefs about mathematics and mathematics instruction. *Journal for Research in Mathematics Education,*


Meeting of the American Association of Colleges for Teacher Education, Chicago, IL.


Macmillan Publishing Company.


APPENDICES
APPENDIX A

CALCULUS WORKSHOP AGENDA

FALL SEMESTER, 1995
Calculus Workshop Agenda
September 5 & 6, 1995
Wilson Hall 1-141

[For all who will be instructing MATH 181 - Calculus in the Fall, 1995 and/or Spring, 1996 semesters; Also open to all other GTA’s interested in Reform Calculus.

Sessions: Tuesday, September 5, 1:30-4:30 PM
Wednesday, September 6, 9-12 AM and 1:30-4:30 PM

Readings: Preface to the Hughes-Hallet et al. text Calculus and pages 2-7 of the Instructor’s Manual with Sample Examinations to Calculus

AGENDA
Tuesday, September 5, 1:30-4:30 PM: [Snacks provided]

- Introduction (Eggert, Kilday)
- Overview of Calculus Reform (Kilday)
- Group structure, dynamics, & philosophy (Kilday)
- GTA group work, homework (Kilday)

Wednesday, September 6, 9-12 AM: [This session is the ideal time for former MATH 181 GTA’s, interested persons, etc. to attend. Open discussion will start at approximately 10 AM; Snacks provided]

- GTA group work and presentations (Kilday)
- Group vs. individual homework (Kilday)
- Instructor, student, consultant, etc. roles (Eggert, Kilday)
- Class structure - First day, week, etc. (Eggert, Kilday)
- First week of class (Eggert, Kilday)

[Noon meal compliments of STEP at the Habit. Those eligible to attend must attend the workshop ALL DAY Wednesday and inform Beth Kilday so reservations can be made (ASAP)]
Wednesday, September 6, 1:30-4:30 PM:
[John Lund will speak at 1:30 PM to all MATH GTA’s. Workshop will immediately follow. All MATH 181 and MATH 182 instructors must attend this session; Snacks provided.]

- Room, equipment, distribution of cabinet keys and TI calculators (Eggert, Taylor)
- Calculators - Use, consultants, help sessions, etc. (Eggert, Ballard, etc.)
- Homework, tests, quizzes, alternative assessments, grading (Eggert, Taylor)
- Weekly instructor meetings (Eggert, Taylor)
COLLABORATIVE LEARNING OBSERVATION CHECKLIST
MATH 181 - FALL SEMESTER, 1995

Instructor ___________________________________ # Students enrolled ______

Date_______ Time/Section______________________ # Students in class ______

Time allotment for group work____________________

Observed Lesson Goal/Objectives______________________________

---

Procedures

1-Objectives for group work are given ________________________
2-Directions for group work are clear ________________________
3-Introduction to group lesson provided _____________________
4-Closure to lesson is provided ____________________________
5-Group quiz is used ________________________________
6-Groups working on assigned homework _____________________
7-Groups reviewing for test or quiz ________________________
8-Groups working to understand a concept ___________________
9-Other ____________________

---

Yes/No with Remarks

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<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(Percentage of Time)</td>
<td>Appl.</td>
<td>&gt;75%</td>
<td>50-75</td>
<td>25-50</td>
</tr>
<tr>
<td>10-Students sit in tight circles</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>11-Students are motivated</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>12-Students perform tasks</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>13-Students collaborate actively</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>14-Students share ideas</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>15-Cooperate socially on calculus</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>16-Students explain concept to group</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>17-Ind. students ask instr. questions</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>18-Groups ask ques. of instructor</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>19-Students record, write, keep notes</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>20-Group member arrive to class late</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>21-Group member leave class early</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>22-Students work alone</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>23-Groups - members not all present</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>24-Individual accountability</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>25-Other</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>26-Other</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>--------------------------</td>
<td>-----------</td>
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</tr>
<tr>
<td><strong>Instructor</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>27-Moves from group to group</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>28-Observes group members</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>29-Is available for assistance</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>30-Asks group if any member knows answer to ques. prior to addressing whole group</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>31-Talks to stud. individually in grp</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>32-Mini-lect to grp when ques. arise</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>33-Answering stud. ques. with ques.</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>34-Gives direct answer when approp.</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>35-Facilitates/encour. collab. work</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>36-Reinforces pos. group work behav.</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>37-Visits each group at least once</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>38-Effectively moves class between group time &amp; lecture</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>39-Other</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>40-Other</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

**Summary of Structure of Groups**

<table>
<thead>
<tr>
<th>Group #</th>
<th>Size</th>
<th># Female</th>
<th># Male</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
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<tr>
<td>3</td>
<td></td>
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<td>4</td>
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<td>5</td>
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<td>6</td>
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<td>7</td>
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<td>8</td>
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<td>9</td>
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<td>10</td>
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<td>11</td>
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<td></td>
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</tr>
<tr>
<td>12</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Totals:**

**Questions/Comments/Remarks**

Seating Chart
APPENDIX C

INSTRUCTOR COLLABORATIVE LEARNING QUESTIONNAIRE

FALL SEMESTER, 1995
MATH 181 INSTRUCTOR QUESTIONNAIRE
FALL SEMESTER, 1995
Date__________________

Please respond to the following questions as honestly as possible. This is not a MSU-Bozeman instructor evaluation.

I. Demographics
(a) Gender (circle): M or F
(b) To the best of your knowledge, how many hours per week during class time do your students work in groups?__________________
(c) To the best of your knowledge, how many hours per week do you lecture?__________________
(d) The section of MATH 181 that you instruct?__________________

II. For each of the following statements, circle the number at right that best indicates your perceptions of group work in your calculus class.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>No Opinion</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1B. Group work helps students understand the calculus concepts better.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>2. When students work in groups, they produce better quality work.</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>3. I like it when different students' thoughts enter into a problem during group work.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>4. I like having 'smart' students in each group.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>5. I like watching students in the groups show others how to work a problem.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>6. Group work involves too much student thinking.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>7. Group work is too slow.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>8. Many groups are nonproductive during group work.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>9. Some groups are usually disorganized during group work.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>10. Groups are seldom off task during group work.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>11. Group sizes of 3 or 4 work the best.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>12. I dislike it when a group member does not contribute during group work.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>13. I believe our class should have lots of group work time.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>14. I like independent work (as opposed to group work).</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>No Opinion</td>
<td>Agree</td>
</tr>
<tr>
<td>---</td>
<td>------------------</td>
<td>----------</td>
<td>------------</td>
<td>-------</td>
</tr>
<tr>
<td>15. I like it when groups get to work on homework during class</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>16. I prefer the lecture method (as opposed to group work)</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>17. I dislike it when individual grades are tied to group work</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>18. I dislike it when students in groups use others as 'crutches'</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>19. I like to use group-graded assignments</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>20. I like to give students instructions on how to effectively work in groups</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>21. I like to let students work in groups during class</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>22. I believe I use a good balance of group work and lecture</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>23. I consider student needs when structuring groups</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>24. Group work is hard to implement</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>25. Group work will work if students like it</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>26. Since group work can be slow, lecturing is often better for the students in my class</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>27. I believe that some class members rely too heavily on their peers during group work</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>28. I believe that teaching students how to communicate in mathematics is important</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>29. Students can discuss more complex problems during group work</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>30. I dislike it when group members are not in class when we do group work</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>31. Group work is distracting</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>32. I like to see peers tutoring peers during group work</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>33. I believe in &quot;rewarding&quot; groups when they work effectively (e.g. extra points, etc.)</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>34. Implementing collaborative learning in the classroom is a technique that must be learned</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>35. The more I use group work in my classroom, the more experienced I become and the better I get at using it</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>
III. Please respond to the following open-ended questions as thoroughly as possible. For each of the questions, state as many comments as you wish.

1. What, if any, do you believe are the *positive features* of group work?

2. What, if any, do you believe are the *negative features* of group work?

3. *Overall*, what are your *honest opinions* of collaborative learning (group work)?

4. How do you believe your students view collaborative learning?
APPENDIX D

STUDENT COLLABORATIVE LEARNING QUESTIONNAIRE

FALL SEMESTER, 1995
MATH 181 STUDENT QUESTIONNAIRE
FALL SEMESTER, 1995

Date __________________

Please respond to the following questions as honestly as possible. This is not a teacher evaluation and the results of this survey will not be revealed to your instructor until after the semester ends.

I. Demographics

(a) Gender (circle): M or F
(b) Ethnicity (circle): African Amer. Asian Amer. Caucasian Hispanic Native Amer. Other ___________________
(c) Class (circle): Freshman Sophomore Junior Senior Graduate
(d) Your expected grade in MATH 181 ______________________
(e) Your Major: __________________________ Minor: __________________________
(f) To the best of your knowledge, how many hours per week during class do you work in collaborative groups? _________________________
(g) The section you are enrolled (or specify class time)? _______________________
(h) Your social security number (for coding purposes)? _______________________

II. For each of the following statements, circle the number at right that best indicates your perceptions of group work in your calculus class.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Agree</th>
<th>Strongly Disagree</th>
<th>Agree</th>
<th>Disagree</th>
<th>No Opinion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A. Group work helps me understand the calculus concepts better...</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>1B. My instructor believes group work helps us better learn the calculus concepts...</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2. When I work in a group I produce better quality work...</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>3. I like it when different students' thoughts enter into a problem during group work...</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>4. I like having &quot;smart&quot; people in my group...</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>5. I like showing people in my group how to work a problem...</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>6. Group work involves too much thinking on my part...</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>7. Group work is too slow...</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>8. My group is not productive during group work...</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>9. My group is usually disorganized during group work...</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>10. My group is seldom off task during group work...</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>No Opinion</td>
<td>Agree</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td>---</td>
<td>-------------------</td>
<td>---------</td>
<td>------------</td>
<td>-------</td>
<td>----------------</td>
</tr>
<tr>
<td>11. Group sizes of 3 or 4 work the best...</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>12. I dislike it when a group member does not contribute during group work</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>13. I wish our class would have lots of group work time</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>14. I like independent work (as opposed to group work)</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>15. I like it when our group gets to work on homework during class</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>16. I prefer the lecture method (as opposed to group work)</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>17. I dislike it when my individual grade is tied to group work</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>18. I dislike it when people in my group use others as “crutches”</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>19. I wish we had more group-graded assignments</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>20. I believe that it is important to learn to work in groups</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>21. I believe that my instructor likes to let us work in groups</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>22. My instructor uses a good balance of group work and lecture</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>23. My instructor considers student needs when structuring groups</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>24. I believe that my instructor feels that group work is hard to implement</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>25. My instructor believes that group work will work if students like it</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>26. My instructor feels that group work can be slow, so lecturing is often better for the students in my class</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>27. My instructor feels that some class members rely too heavily on their peers during group work</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>28. My instructor feels that it is important to teach students how to communicate</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>
III. Please respond to the following open-ended questions as thoroughly as possible. For each of the questions, state as many comments as you wish.

1. What, if any, do you believe are the positive features of group work?

2. What, if any, do you believe are the negative features of group work?

3. What previous experiences have you had with collaborative learning or group work?

4. Overall, what are your honest opinions of collaborative learning (group work)?

5. How do you believe your instructor views collaborative learning (group work)?
APPENDIX E

INSTRUCTOR INTERVIEW INSTRUMENT

FALL SEMESTER, 1995
MATH 181 Instructor Interview
MSU-Bozeman, Fall Semester, 1995

Opening Statement:

I would like to tape record your comments to the following questions so that I don't miss any of it. I don't want to take the chance of relying on my notes and "thereby miss something that you say or inadvertently change your words somehow. So, if you don't mind, I'd like very much to use the recorder. If at any time during the interview you would like to turn the tape recorder off, all you have to do is press this button on the microphone, and the recorder will stop" (Patton, 1980, p. 247).

As you know, I am interested in the use of collaborative learning in the MATH 181 course. I am also interested in how you, a graduate teaching assistant, use collaborative learning in your class.

"Remember that what you say is confidential, while your comments will contribute to the knowledge base of my study, you would never be personally identified with the information you provide. My hope is that you will be completely candid in your responses, so that I might create an accurate picture of the role of graduate teaching assistants. I will provide you with a [transcribed hardcopy] of the tape from this interview. If you want to add or delete information later, or clarify any responses, I encourage you to do that" (Thoresen, 1994).

Do you have any questions about this study before we begin? If not, please respond to the following open-ended questions as thoroughly as possible. For each of the questions, state as many comments as you wish. Remember that you can end this interview at any time. Also, if there are any questions that are unclear, don't hesitate to stop and ask for clarification.

1. What degree program are you in, where are you in the program, and what do you plan to do following your degree? Why did you decide to teach while obtaining your degree? Do you enjoy teaching and do you plan to teach in the future?
2. Elaborate on all your past experiences with collaborative learning (prior to MATH 181) in which you have been involved (as a student, instructor, observer, etc.).

3. How much class time is devoted to group work, lecture, etc. in your MATH 181 class? (Address weekly.)

4. How were the student groups formed at the beginning of the semester? (Describe the process from initial groupings to the restructuring of permanent groups and address such considerations as size, male/female, calculators, major, etc.)

5. Are any special seating arrangements used during class times when students are learning collaboratively?

6. Describe how you are grading student work in your class. (Address homework, quizzes, presentations, notebooks, portfolios, student write-ups, etc.)
   Do you have special procedures and rules which you expect students to follow when students work in small groups during class and when they hand in written work? Explain.

7. During the GTA collaborative learning workshop, what best helped prepare you to use collaborative learning in your class?

8. What else could have been discussed in the GTA collaborative learning workshop that would have helped prepare you in using collaborative learning in your class?

9. What do you think are the best features of student group work?

10. What do you feel are the negative features of student group work?

11. What other opinions do you have about the calculus course? What else should instructors be thinking about?
APPENDIX F

STUDENT INTERVIEW INSTRUMENT

FALL SEMESTER, 1995
MATH 181 Student Interview  
MSU-Bozeman, Fall Semester, 1995

Opening Statement:

I would like to tape record your comments to the following questions so that I don’t miss any of it. I don’t want to take the chance of relying on my notes and “thereby miss something that you say or inadvertently change your words somehow. So, if you don’t mind, I’d like very much to use the recorder. If at any time during the interview you would like to turn the tape recorder off, all you have to do is press this button on the microphone, and the recorder will stop” (Patton, 1980, p. 247).

As you know, I am interested in the use of collaborative learning in the MATH 181 course. I am also interested in how you, an undergraduate student, perceive collaborative learning in your class.

“Remember that what you say is confidential, while your comments will contribute to the knowledge base of my study, you would never be personally identified with the information you provide. My hope is that you will be completely candid in your responses, so that I might create an accurate picture of the role of [undergraduate engineering calculus students]. I will provide you with a [transcribed hardcopy] of the tape from this interview. If you want to add or delete information later, or clarify any responses, I encourage you to do that” (Thoresen, 1994).

Do you have any questions about this study before we begin? If not, please respond to the following open-ended questions as thoroughly as possible. For each of the questions, state as many comments as you wish. Remember that you can end this interview at any time. Also, if there are any questions that are unclear, don’t hesitate to stop and ask for clarification.

- Male or Female
- Ethnicity (if you so choose to answer)
- SSN (for coding purposes)
1. What degree program are you in and where are you in the program (major, minor, class, etc.)?

2. Elaborate on all your past experiences with collaborative learning (prior to MATH 181) in which you have been involved (as a student, instructor, observer, etc.).

3. As a MATH 181 student, how often are you attending class? (For example, you might estimate the number of absences you’ve had in the past five weeks.) How much class time is devoted to group work, lecture, etc. in MATH 181? (Address weekly.) Do you think there should be more or less time devoted to group work, lecture, etc.? Explain.

4. How were the student groups formed at the beginning of the semester? (Describe the process.) Do you think this was a fair way of selecting groups? What, if anything, would you have preferred your instructor to do differently in the forming of groups?

5. How were and/or are your groups “structured?” (Address size, male/female, major, other considerations.) Explain the structure of your group. Do you think this is a good way to structure the groups? Explain.

6. Are any special seating arrangements used during class times when collaborative learning (small group work) is used? Explain.

7. How is your instructor grading your MATH 181 work? (Address homework problems, portfolios, notebooks, group and/or individual quizzes, presentations, etc.) Does your instructor have special procedures and rules which he/she expects students to follow when students work in small groups during class and when they hand in written work? Explain.
8. Do you believe you instructor is comfortable teaching or facilitating a collaborative learning (small group work) lesson? Why or why not? Do you believe your instructor like teaching whether is be lecturing or utilizing small group work?

9. What do you think are the best features of student group work?

10. What do you feel are the negative features of student group work?

11. What other opinions do you have about the calculus course? What else should instructors be thinking about?
APPENDIX G

WEEKLY COLLABORATIVE LEARNING LOG

FALL SEMESTER, 1995
**Weekly MATH 181 Collaborative Learning Log**
Fall Semester, 1995

Date _______________________
Instructor ____________________
Section _______________________

**WEEK OF _______________________

Fill in the following table with the number of minutes spent during class for each of the following teaching techniques (per class period).

<table>
<thead>
<tr>
<th></th>
<th>MON</th>
<th>TUES</th>
<th>WEDN</th>
<th>THURS</th>
<th>FRI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecture</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collabor. Learning</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other (specify)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Lecture** means that the instructor is in charge of the whole class where he/she lectures on content and answers questions for the benefit of the whole class.

**Collaborative Learning** is any small group work that may be used for doing homework, a quiz, an activity, etc.

**Other** includes all other work that may be an individual quiz, student presentation, individual homework or activity, etc. (Nonlecture, non-collaborative learning activity.)
APPENDIX H

COMPREHENSIVE FINAL EXAMINATION

FALL SEMESTER, 1995
Math 181 Final December 20, 1995 Name:__________________________

Be neat o o o Show your work Instructor/section:________________________

<table>
<thead>
<tr>
<th>Problem</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>Sheet 1</th>
<th>Sheet 2</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Points</td>
<td>20</td>
<td>12</td>
<td>30</td>
<td>12</td>
<td>32</td>
<td>6</td>
<td>112</td>
<td>88</td>
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<td>Score</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. The following data was collected for the differential function \( F \), and \( F' = f \):

\[
\begin{array}{c|cccc}
 x & 1.4 & 1.5 & 1.6 & 1.7 \\
 F(x) & 2.315 & 2.382 & 2.451 & 2.525 \\
\end{array}
\]

(a) Estimate \( f(1.6) \).

(b) Use your answer above to estimate the value of \( F(1.61) \).

(c) Using a Riemann sum, give a estimate of \( \int_{1.4}^{1.7} F(x) \, dx \), as accurately as possible.

(d) Evaluate: \( \int_{1.4}^{1.7} f(x) \, dx \)

2. Given the following three graphs. One is the graph of a function \( F \), the other graphs are the first derivative, \( F' \), and the second derivative, \( F'' \). Clearly identify each graph.

![Graphs of F, F', F''](image)

3. Find the derivatives of the following functions. Do not simplify.

(a) \( F(x) = \left[ \frac{\sin(-4x)}{10e^x} \right]^{14} \)

(b) \( g(t) = t^2 \cdot e^{-t} \cdot \ln(3t - 2) \)

(c) \( V(t) = \frac{1}{14\pi} |C(t)|^2 \cdot h(t) \) Find \( \frac{dV}{dt} \) where \( C(t) \) and \( h(t) \) are differentiable functions of \( t \).

4. Let \( g(x) = x^3 - 3x^2 + 2 \). Find the local maximum(s) and local minimum(s) of \( g \). Remember to verify your answer using the second derivative test. Be sure your work is clear.
5. Let the values of the functions and derivatives of \( f \) and \( g \) be given by the entries of the table. Let \( H(x) = f(g(x)) \), \( K(x) = \frac{f(x)}{g(x)} \), \( L(x) = f(x^2 - 1) \) and \( M(y) = f^{-1}(y) \).

\[
\begin{array}{c|cccccc}
   x & f & f' & f'' & g & g' & g'' \\
   \hline
   -2 & 0 & 2 & -1 & 1 & 5 & -1 \\
   -1 & 4 & 3 & -4 & 2 & -1 & 4 \\
   0 & 2 & -1 & 3 & 0 & 7 & -2 \\
   1 & -1 & 6 & 10 & 1 & 3 & 2 \\
   2 & 3 & 5 & 4 & -2 & 6 & 5 \\
\end{array}
\]

Find:

- \( H(-1) \)
- \( K(-1) \)
- \( L(-1) \)
- \( M(-1) \)

Write a formula for \( H''(x) \) and evaluate \( H''(-1) \).

6. If the value of \( \int_{3}^{5} F(t) \, dt = 14 \), what is the average value of the function \( F \) between \( x = 3 \) and \( x = 5 \)?

Math 181 Final December 20, 1995 Name: ______________________________

Be neat o o o Show your work Instructor/section: ____________________________

<table>
<thead>
<tr>
<th>Problem</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Points</td>
<td>28</td>
<td>15</td>
<td>15</td>
<td>18</td>
<td>12</td>
<td>88</td>
</tr>
</tbody>
</table>

7. For \( f \) an increasing differentiable function with domain all real numbers, match the most reasonable quantity from the list to the right with the statements on the left. Not all quantities need to be used. Some quantities may be used more than once.

- For \( b \) close to \( a \), let \( h = b - a \). The slope of the line between the points \((a, f(a))\) and \((b, f(b))\) is given by \( \frac{f(b) - f(a)}{h} \).
- The error between the integral of \( f \) and the Riemann sum of \( f \), where \( h = \frac{b - a}{n} \) represents the length of the individual subdivisions, is found by \( h \cdot [f(b) - f(a)] \).
- The integral of \( f' \) between \( a \) and \( b \) is \( f'(a) \).
- In order to check if the tangent line is below the curve near \( a \), you should check \( f''(a) \).
- For \( b \) close to \( a \), let \( h = b - a \). The derivative of \( f \) at \( a \) is estimated by \( f(a) + f'(a) \cdot h \).
- For \( b \) close to \( a \), let \( h = b - a \). The value of \( f(b) \) is estimated by \( f(a) \).
- The function \( f \) could have an inflection point at \( a \) if zero is the value of \( f''(a) \).
8. Find \( \frac{dy}{dx} \), given \( xy^3 - x^5y^2 = 4 \) and \( y \) is a differentiable function of \( x \). Then find the slope of the line tangent to the graph of the given equation at the point \((1, 2)\).

9. Use Newton's Method to estimate a root of

\[ f(x) = x - \cos x \]

using the initial estimate to be \( x_0 = \frac{\pi}{2} \). You need only find the values for \( x_1 \) and \( x_2 \). Be sure your work is clear, the answers alone are not acceptable. A calculator is not needed, if you have some knowledge of the values of trigometric functions. If you use a calculator, you are required to list at least 5 decimals.

10. Suppose the shipping office can accept a cylindrical package (that is the shape of a soda can) where the sum of the height and girth (the circumference of its circular cross section) is at most 90 inches.

   What is the maximum volume of the cylindrical package that can be shipped?

11. Sketch a possible graph of \( y = f(x) \) using the given information about the derivatives \( y' = f'(x) \) and \( y'' = f''(x) \). Assume that the function is defined and continuous for all real \( x \).

\[
\begin{array}{cccc}
\quad & y' = 0 & y' \text{ undefined} & \quad \\
y' < 0 & \quad & y' > 0 & y' < 0 \\
\quad & x_1 & \quad & x_2 \\
y'' \text{ undefined} & \quad & \quad & \quad \\
y'' > 0 & y'' < 0 & \quad & \quad \\
\end{array}
\]
APPENDIX I

COLLABORATIVE LEARNING DIAGRAM
Table 1: Student Summary by Gender, Ethnicity, Class and Major

<table>
<thead>
<tr>
<th>Instructor</th>
<th>Gender</th>
<th>Ethnicity</th>
<th>Class</th>
<th>Major</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
<td>White</td>
<td>Asian</td>
</tr>
<tr>
<td>Al</td>
<td>13</td>
<td>2</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td>Ben</td>
<td>17</td>
<td>3</td>
<td>19</td>
<td>1</td>
</tr>
<tr>
<td>Clyde</td>
<td>22</td>
<td>5</td>
<td>26</td>
<td>1</td>
</tr>
<tr>
<td>Dan</td>
<td>19</td>
<td>5</td>
<td>24</td>
<td>0</td>
</tr>
<tr>
<td>Ellen</td>
<td>17</td>
<td>6</td>
<td>21</td>
<td>2</td>
</tr>
<tr>
<td>Fran</td>
<td>17</td>
<td>7</td>
<td>22</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 2: Percent Breakdown of Total Class Time

<table>
<thead>
<tr>
<th>Instructor</th>
<th>Lecture</th>
<th>Collabor. Learning</th>
<th>Quiz</th>
<th>Review</th>
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Table 3: Weekly Observation Schedule

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Table 4: Observation Summary

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<th>Average of Students in Class for GW</th>
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APPENDIX K

STUDENT AVERAGE vs. INSTRUCTOR

CHARTS
Instructor vs. Student Average (Clyde, Survey 1)

Instructor vs. Student Average (Clyde, Survey 2)

Instructor vs. Student Average (Clyde, Survey 3)
Instructor vs. Student Average
(Dan, Survey 1)

Instructor vs. Student Average
(Dan, Survey 2)

Instructor vs. Student Average
(Dan, Survey 3)
Instructor vs. Student Average
(Fran, Survey 1)

Instructor vs. Student Average
(Fran, Survey 2)

Instructor vs. Student Average
(Fran, Survey 3)