# Teacher-student interactions in SIMMS and non-SIMMS mathematics classrooms

by Birdeena Crandall Dapples

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



Abstract:
The Systemic Initiative for Montana Mathematics and Science (SIMMS) project is creating a program for grades 9-12 which consists of integrated mathematical curricular materials, alternative forms of assessment, and constructivist pedagogical methods. One of the teacher's roles is that of a facilitator of learning with the students taking more responsibility for their learning. The facilitator role represents a paradigm shift for many mathematics teachers. The study documented teacher-student interactions of mathematics teachers implementing the SIMMS curriculum and its accompanying constructivist methodology. The study examined the teacher-student interactions of four SIMMS-prepared teachers in their SIMMS and non-SIMMS classrooms over a four-month period during the first year of the experimental program. The findings were as varied as the individual personalities of the teachers, but there was a decided increase in the use of student-centered interactions in the SIMMS classrooms as compared to the non-SIMMS classrooms. However, the majority of the classroom interactions in both types of classrooms were still teacher-centered. Curricular materials based on constructivist ideas incorporating cooperative learning groups help encourage the use of student-centered teaching. However, extended professional development experiences are essential to help teachers translate the recommended constructivist methodology into appropriate teacher-student interactions.

# TEACHER-STUDENT INTERACTIONS IN SIMMS AND NON-SIMMS MATHEMATICS CLASSROOMS

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A thesis submitted in partial fulfillment
of the requirements for the degree

of

Doctor of Education

MONTANA STATE UNIVERSITY
Bozeman, Montana

January 1994

D378
D2395



APPROVAL

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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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Date January 18, 1994

"Mathematics teaching consists primarily of the mathematical interactions between a teacher and children" (Steffe & Killion, 1986, p. 207).

# ACKNOWLEDGMENTS

I wish to thank my committee members for their support and assistance in this project. In particular, I would like to thank Dr. Glenn Allinger, who was always ready to listen to my problems. His use of student-centered teaching helped me to "construct" my understanding of professional development and teacher-student interactions. I appreciate Dr. Elisabeth Charron's assistance in the area of qualitative research and her willingness to take over as co-chair of my committee in "mid-stream."

The SIMMS project personnel, from the directors to the secretaries, have been very supportive and helpful with this project and I greatly appreciate their cooperation. I owe a debt of gratitude to the four teachers who allowed me to observe their classes as they pre-piloted new curricular materials.

I also wish to thank my daughter, Cathryn, for reading many versions of this paper and offering gentle constructive criticism.

This material is based upon work supported by the National Science Foundation under Cooperative Agreement No. TPE 9150055. The Government has certain rights in this material. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the National Science Foundation.

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# ABSTRACT

The Systemic Initiative for Montana Mathematics and Science (SIMMS) project is creating a program for grades 9-12 which consists of integrated mathematical curricular materials, alternative forms of assessment, and constructivist pedagogical methods. One of the teacher's roles is that of a facilitator of learning with the students taking more responsibility for their learning. The facilitator role represents a paradigm shift for many mathematics teachers. The study documented teacher-student interactions of mathematics teachers implementing the SIMMS curriculum and its accompanying constructivist methodology. The study examined the teacher-student interactions of four SIMMS-prepared teachers in their SIMMS and non-SIMMS classrooms over a four-month period during the first year of the experimental program. The findings were as varied as the individual personalities of the teachers, but there was a decided increase in the use of student-centered interactions in the SIMMS classrooms as compared to the non-SIMMS classrooms. However, the majority of the classroom interactions in both types of classrooms were still teacher-centered. Curricular materials based on constructivist ideas incorporating cooperative learning groups help encourage the use of student-centered teaching. However, extended professional development experiences are essential to help teachers translate the recommended constructivist methodology into appropriate teacher-student interactions.

# OVERVIEW OF STUDY

## Introduction

Two major contributors to a student's success in school are the contexts in which the school subjects are taught and the teacher-student interactions within the classroom (Chismar, 1985; Mehan, 1982; Renninger & Winegar, 1985; Troisi, 1983). Currently some mathematics curricular reform projects are trying to address the context issue by writing materials that focus on applications of mathematics to the student's world. However, unless these projects also address the other main contributor to student success, classroom interactions, they will not get a complete picture of the impact of their reform. Both the context of the subject matter and the teacher-student interactions affect student success and consequently the success of the reform.

The Systemic Initiative for Montana Mathematics and Science (SIMMS) is funded by the National Science Foundation (NSF) and the State of Montana and administered by the Montana Council of Teachers of Mathematics (MCTM). SIMMS is a curricular reform project which is creating an integrated mathematics program intended for all students in grades 9-12. There is strong support for this type of program across the nation as revealed in a 1989 study by the Integrated Mathematics Project (IMP) under the sponsorship of the Exxon Corporation (Beal, Dolan, Lott, & Smith, 1989). SIMMS is attempting to implement the concept of integrated mathematics which emerged from the IMP study. A key feature of the IMP model curriculum is the use of applications from the "real-world" as a context for the mathematics. There is also a strong emphasis on enhancing the students' problem-solving skills. For a more complete description of the IMP model, see page 9.

A curricular focus on problem-solving skills will necessitate a classroom environment which encourages students to take an active part in making sense of a problem-solving situation for themselves, rather than simply memorizing formulas. The National Council of Teachers of Mathematics (NCTM) and the National Research Council (NRC) encourage teachers to interact with their students in ways that actively involve the students in the learning process (National Council of Teachers of Mathematics [NCTM], 1989 &1991; National Research Council [NRC], 1989). The NCTM Curriculum & Evaluation Standards for School Mathematics (1989) advocates that teachers adopt a "constructive, active view of the learning process" (p. 10). The NRC report Everybody Counts says that

> educational research offers compelling evidence that students learn mathematics well only when they construct their own mathematical understanding. . . . This happens most readily when students work in groups, engage in discussion, make presentations, and

in other ways take charge of their own learning. (NRC, 1989, p. 58)

Unfortunately, the typical mathematics classroom in this country does not reflect this constructivist paradigm. The scene, which is played out in numerous classrooms each day, is one of students sitting in desks aligned in neat rows. Normally, the teacher shows the students how to do some of the more difficult problems from the previous day's assignment, lectures on the new material for the day, and assigns problems from the textbook at the end of the day's lesson. Students who have been taught in this manner for ten or twelve years are often unable to apply the mathematics they have learned. They also lack the problem solving and communication skills that today's business community desires or the skills necessary to be informed consumers and citizens (Montana Science Education Board [MSEB], 1991; NRC, 1989).

In contrast, a mathematics classroom which implements the SIMMS integrated mathematics project is envisioned as one in which

- the mathematics content is integrated;
- the curricular materials help the students to construct their own meanings out of mathematical situations through self-directing activities;
- the teacher is a facilitator of learning, not only a purveyor of knowledge;
- appropriate technology is utilized;
- a variety of instructional formats are used including cooperative learning groups and individual projects; and

- a variety of alternative assessment methods are used including open ended questions. (Systemic Initiative for Montana Mathematics and Science [SIMMS], 1992a, 1993)

This type of classroom environment may be very different from the one to which many mathematics teachers are accustomed. The SIMMS project recognizes that teachers may need to make a shift in their teaching practice "away from an 'instrumentalist' practice, where computational procedures are ends in themselves, toward a 'constructivist' practice rooted in real world applications" (SIMMS, 1992a, p. 5).

## Statement of Problem

Teacher-student interactions are one way teachers put their philosophies of teaching and learning into practice. Many research studies have reported on the strong influence of various types of teacher-student interactions on students' success in school (Chismar, 1985; Mehan, 1982; Renninger, 1985; Samuelowicz & Bain, 1992; Troisi, 1983). These studies noted that while students participate in classroom interactions, the teacher signals "the type and amount of participation permitted" (Chismar, 1985, p. 23). Consequently, those classroom interactions which involved the teacher were the primary interest of this study.

The study investigated the teacher-student interactions in the SIMMS and non-SIMMS classrooms of teachers who pre-piloted the SIMMS ninth grade program. This researcher looked for patterns of teacher-student interactions across a teacher's SIMMS and non-SIMMS classrooms or differences in interactions between a teacher's SIMMS and non-SIMMS classrooms. Of special interest were interactions as listed in the description of a facilitator of learning (see page 8).

The NCTM Curriculum Standards (1989) described recommended instructional practices for 9-12 mathematics classes in terms of teacher-student interactions. Teachers were advised to involve students in constructing mathematical ideas, ask questions that promote student interaction, use a variety of instructional formats, and have students communicate mathematical ideas orally and in writing (NCTM, 1989). The intent of the SIMMS project was to design curricular materials which enabled students to construct their own mathematical understandings from self-directed learning situations, thereby shifting the teacher's role to one in which the type of interactions described by the NCTM Standards are used (SIMMS, 1992a).

Several Montana high schools were chosen to field test the first modules of the SIMMS program, in their draft form. In order to acquaint the teachers who were to be involved in the field test with the curricular materials, technology, and recommended pedagogy, a six-week summer institute was held during the summer of 1992, prior to the pre-piloting year. The institute gave the teachers an opportunity to study the methodology advocated by the SIMMS project, experience SIMMS curricular materials (in draft form), learn to use recommended technology, discuss alternative pedagogy, and experiment with instructional situations. Some of the institute teachers were chosen to pre-pilot the full set of modules for the ninth grade (Level One) while others pre-piloted only three or four modules.

Other SIMMS studies looked at student achievement. This study documented the type and frequency of teacher-student interactions in both SIMMS and non-SIMMS classrooms. The documentation of these interactions in the SIMMS classrooms was intended to assist the SIMMS project in interpreting student achievement results, especially since a set of numerical scores at the end of the school year does not give a complete picture of curricular change. The identification of patterns of teacher-student interactions was intended to help document how the material was taught and whether the proposed constructivist methodology was implemented. A comparison of teacher-student interaction patterns between a teacher's SIMMS and non-SIMMS classes is also intended to help the SIMMS Project assess the effect of their curricular materials on teaching practices.

## Timeline of Study

April 1992

Contacted teachers for pre-institute observations and permission to include them in the study.

May 1992

Conducted pre-institute classroom observations and teacher interviews with nine institute participants.

June - July 1992

Selected set of five teachers, from original nine, to participate in study (see page 26).

Selected methods of data collection: Flanders Interaction Coding Schema, classroom observations, and personal interviews.

September 1992

Conducted preliminary visits to study teachers.

Refined data collection techniques (see page 32).

October 1992

Made first visit to study teachers. Observed two consecutive days in one SIMMS and one non-SIMMS class. Conducted first interview.

November-December 1992

Made second visit to study teachers - same data collection procedures.

January 1993

Made third visit to study teachers - same data collection procedures.

February - March 1993

Transcribed classroom and interview audiotapes.

April - June 1993

Finalized code list for interactions.

Analyzed code summaries, field notes and interview statements.

July 1993

Reviewed findings with study teachers.

## Definitions

Constructivism: An epistemology which describes knowledge as a personal construction based on a person's experience (Ernest, 1989; Noddings, 1990; von Glasersfeld, 1990).

Facilitator of learning: An instructor who

- uses a variety of instructional situations;
- assists students in organizing cooperative learning groups;
- has students do class presentations;
- demonstrates a positive attitude toward mathematics;
- demonstrates a positive attitude toward students, regardless of gender or ethnic origin;
- demonstrates use of appropriate technology;

- encourages students to use appropriate technology;
- requires students to express mathematical ideas in written and oral form;
- uses alternative assessment tools;
- encourages discussion among students about problems and possible solutions;
- attempts to understand the student's rationale for his or her work;
- brings up evidence that conflicts with students' interpretation, so they can re-examine their thinking;
- asks process-oriented questions;
- asks open-ended questions;
- asks judgment questions;
- moderates class discussions on student generated ideas;
- helps students to rely on themselves to determine whether a solution is mathematically correct; and
- creates a classroom environment in which students are encouraged to take risks. (NCTM, 1991 &1989; Peterson, 1988; Rogers, 1969; SIMMS, 1993 &1992a)

Integrated Mathematics Project Concept: An integrated mathematics program for all students

- consists of topics chosen from a wide variety of mathematical fields and blends those topics to emphasize the connections and unity among those fields;

- emphasizes the relationships among topics within mathematics as well as between mathematics and other disciplines;
- each year, includes those topics at levels appropriate to students' abilities;
- is problem-centered and application-based;
- emphasizes problem-solving and mathematical reasoning;
- provides multiple contexts for students to learn mathematical reasoning;
- provides continual reinforcement of concepts through successively expanding treatments of those concepts; and
- makes use of appropriate technology. (Beal et al., 1989, p. 4)

SIMMS classroom: A high school mathematics classroom in which

- SIMMS-generated integrated mathematics materials are used;
- graphics calculators, computers, and other appropriate technology are used as an integral part of the lesson;
- cooperative learning groups are a significant organizational structure;
- a variety of assessment methods are used, including open-ended questions; and
- the teacher assumes the role of facilitator of learning. (SIMMS, 1993,1992a)

Non-SIMMS classroom: A high school mathematics classroom which lacks at least one of the characteristics of a SIMMS mathematics classroom.

# REVIEW OF RELEVANT RESEARCH AND THEORY

The following pages contain a review of literature pertinent to the thesis problem involving teacher-student interactions. The topics considered are the constructivist theory of knowledge and learning and its effect on teaching, types of teacher-student classroom interactions, and the process by which teachers adapt their philosophies of teaching and learning, and thereby their classroom behavior.

## Constructivism

The Systemic Initiative for Montana Mathematics and Science (SIMMS) Project recognized the importance of having a theoretical basis for any curricular change. Reform projects in mathematics education prior to 1985 have been characterized, in research summary publications, as failing to adequately identify the goals desired and lacking a theoretical foundation (Kilpatrick, 1992; Wittrock, 1986). Robert Davis, a mathematics educator from Rutgers University, reviewed research on several "failed new math" reform projects of the 1960s and 1970s. He concluded that one reason they were considered to be failures was because they "lacked an adequate theory of how students learn mathematics"

(Davis, 1990, p. 94). Fortunately, this situation is changing as current mathematics education researchers attempt to link the complexity of classroom practices to theories of learning (Kilpatrick, 1992).

To this end, the SIMMS Project has developed a theoretical foundation for its program, and the constructivist theory of knowledge is a major part of that basis. Constructivist theory holds that knowledge does not exist separately from the knower and that each person creates his or her own knowledge of the world, or a school subject, through personal experiences (Ernest, 1989; Noddings, 1990; von Glasersfeld, 1990). Even in seemingly passive lecture situations, people are actively "constructing" their own understanding of what the lecturer is saying, fitting it into the framework of their previous experience.

Because constructivism appears to describe the way an understanding of mathematics is gained, it is currently receiving a great deal of attention in mathematics education literature. A survey of the Educational Resources Information Center (ERIC) database entries from the past ten years, revealed 80% of the entries relating to mathematics and constructivism were written during the past five years. To illustrate that constructivism is not just the latest "buzzword" in mathematics education, the following brief review chronicles the heritage of constructivism which goes back centuries.

In The Republic, Plato proposed the existence of a perfect realm of ideas, separate from the physical world (Plato, 1986/ 350 BC). This separation of the realm of ideas and the physical world suggests the infancy of constructivism. During the early 1600s, Rene Descartes questioned the validity of the notion that our world is an absolute entity, common to all people (Beardsley, 1960). About a hundred years later Immanuel Kant elaborated on that idea by proposing that reality is constructed by the mind that "knows it" (Marias, 1967). This ideas is the cornerstone of constructivism. In that same era, Jean Jacques Rousseau applied this idea to education. In Emile, he wrote that students should be allowed to learn some things for themselves in their own way. "Whatever he knows, he should know not because you have told him, but because he has grasped it himself" (Boyd, 1956, p. 73).

More recently, during the 1960's, Jean Piaget put forth the "constructivist" idea that knowledge is actively built by each person, not passively received. He saw the acts of assimilation and accommodation as ways people refined and updated their knowledge as they gained more experiences, i.e., as they learned (von Glasersfeld, 1990). The process of constructing knowledge involves encountering situations that challenge one's previously held concepts, reflecting on their relevance, and then, if appropriate, adapting one's concepts in line with the new experiences (Piaget, 1970).

Piaget, along with other proponents of constructivism, felt that the experiences through which we construct our knowledge are not limited to the physical world. We are social beings, and social interactions play a large role in helping us make sense of our world (Furth, 1969; Piaget, 1970). Students construct their understanding of a school subject as they interact with the teacher and other students. As they share their ideas with others, they are comparing their concepts with those held by others and adapting those that no longer fit their enlarged experience. This extension of constructivist theory, called social constructivism, is advocated by many mathematics educators (Baroody & Ginsburg, 1990; Bauersfeld, 1988; Ernest, 1989). Mathematical knowledge is seen as having resulted from interactions within a mathematics community, the members of the community having negotiated acceptable mathematical meanings from common problem situations (Cobb, Wood & Yackel, 1990; Ernest, 1989).

Jere Confrey, a mathematics educator at Cornell University, commented on how constructivist ideas impact pedagogy. "When one applies constructivism to the issue of teaching, one must reject the assumption that one can simply pass on information to a set of learners and expect that understanding will result" (Confrey, 1990, p. 109). Richard Skemp, a noted mathematics educator from England, holds that "concepts of a higher order than those which people already have cannot be communicated to them by definition, but only by arranging for them to encounter a suitable collection of examples" (Skemp, 1987, p. 83). In the classroom the teacher's structuring of, and guidance through, mathematics problem situations helps the students construct their knowledge in line with that of other students and accepted practice (Confrey, 1990; Noddings, 1990).

If teachers accept constructivist theory it must impact the way they interact with their students. "If indeed a student does not understand, constructivism tells us that merely showing the student 'the right way' to do the problem will probably not suffice to straighten things out. We must probe deeper, and make contact with the student's ways of thinking" (Davis, Mayer, & Noddings, 1990, p. 188). This requires students to communicate their ideas and the teacher to be open to different frames of reference.

Studies have shown that constructivist methodology does "work" in the classroom. Paul Cobb and others (1991) studied the effects, on elementary school students, of mathematical activities and their accompanying instruction which were guided by constructivist ideas. "Students [engaged] in small group collaborative mathematical activity and then in teacher-orchestrated class discussions of their problems, interpretations, and solutions" (p. 6). Cobb concluded that the performance of the experimental group was superior to that of the control group in both problem-solving and traditional computational tasks.

Other researchers who studied instructional formats designed to overcome students' mathematical misconceptions concluded that the most effective format was one in which the students took an active role in their learning (Baird & White, 1984; Novak & Gowin, 1984; Nussbaum, 1982). And, as noted by Jere Confrey (1990), "The philosophical approach that argues most vigorously for an active view of the learner is constructivism" (p. 107). Constructivist theory can offer explanations of how students learn, but it remains for teachers to translate that theory into classroom actions.

## Teacher-Student Interactions

Research studies have shown that classroom interactions are one of the main factors affecting student success (Chismar, 1985; Mehan, 1982; Renninger, 1985; Troisi, 1983). These interactions are one way teachers can put constructivist theory into practice. The teacher-student interactions envisioned by SIMMS and the National Council of Teachers of Mathematics (NCTM)) cast the teacher in a constructivist-type role of a facilitator of learning rather than a purveyor of knowledge. This type of teaching has also been labeled "student-centered" and is an important part of a constructivist methodology. It involves teacher-student interactions which attempt to help students construct their own meanings from mathematical situations as advocated by constructivist theory. This is in contrast to "teacher-centered" teaching which keeps the students' attention focused on the teacher's view of the subject being studied.

The student-centered teaching approach contends that the student has the central role in the learning process.

> In student-centered teaching, students' existing conceptions are the starting point of an interactive teaching/learning process and students are helped by teacher's activities to construct their own knowledge . . . in line with that shared by the experts in the field. (Samuelowicz, 1992, p. 104)

Note the difference between the above definition and that of the more traditional "teacher-centered" teaching.

> In teacher-centered teaching students' existing conceptions are not taken into account, a teacher possesses the knowledge and transmits or imparts it to students. (Samuelowicz, 1992, p. 104)

The use of student-centered instruction is encouraged by many educators as a way to help raise students' self esteem and promote more academic success (Higgins, 1987; Knight, 1987; Stover, 1990). Student-centered teaching has increased student participation in the classroom as well as improved academic performance (Kelly, 1985; Troisi, 1983). Sharing control of instructional situations with the students is one form of student-centered teaching. For example, the teacher could involve students more "by not answering a direct question, perhaps deflecting it by asking other pupils what they think, or by inviting the questioner to explain what he has found out so far" (Pimm, 1987, p. 51). Instead of cutting off interaction with a direct answer, students are encouraged to actively participate. Students can discuss possible solutions, determine the correctness of the solution based on mathematics, not "teacher authority," and gain confidence in their mathematical abilities.

The cooperative learning instructional format is another format for student-centered teaching. Neil Davidson (1990), noted author and researcher in the area of cooperative learning, reviewed over 80 research studies on cooperative learning and reported that in the majority of these studies the students in cooperative learning (student-centered) classes had better academic performance than the students in the control groups. "Students are not bored in class; many of them like mathematics more than when involved in teacher-centered approaches" (p. 60). Cora Agatucci (1989) found in her research at the college level that the cooperative learning structure was particularly helpful for traditionally "under-represented" groups of students, such as Hispanics.

The NCTM Standards, in describing student behaviors with action words like investigate, formulate, and verify, advocate a shift of emphasis in the student's role from passive recipient to active participant. They note that an accompanying shift is required in the teacher's role from a dispenser of information to a "facilitator of learning" using student-centered teaching strategies ([NCTM], 1989, p. 128). Today, teachers and teacher educators are trying to determine exactly what being a facilitator of learning, or student-centered teacher, means for the mathematics classroom.

The definition of facilitator of learning compiled by the researcher for this study (see page 8) was drawn from the NCTM Curriculum Standards, NCTM Professional Standards, SIMMS philosophy statements, and other current mathematics education literature. The definition describes teacher actions and teacher-student interactions which attempt to translate student-centered, constructivist theory into classroom practice. The items listed are very diverse and many will not be addressed in this study. All were included to provide a more complete overview of the SIMMS project's ideal facilitator of learning. It was assumed that the curricular materials would provide appropriate mathematical problem situations. The listed interactions were seen as facilitating students' work as they experimented, conjectured, communicated ideas, and constructed valid mathematical concepts from the given situations.

## Teacher Change

How can teacher educators assist teachers in adopting constructivist-based methodology and promote different types of teacher-student interactions? "Constructivism does not offer pedagogical recipes or convenience. It asks much of us. Many familiar tools, and many familiar attitudes, must be questioned, modified, or just plain discarded" (Davis, Maher, & Noddings, 1990, p. 188). Michael Fullan, educational researcher and consultant to many educational reform projects, noted the importance of applying constructivist ideas to teacher enhancement. He suggests that teachers need to be given the opportunity to construct their own understanding of a curricular change or innovation much as their students will construct their own mathematical meanings of mathematical situations (Fullan, 1991).

The NCTM Professional Standards for Teaching Mathematics (1991) is not alone in supporting the idea that a structured, supportive professional-development environment must be provided in order for teachers to reshape their classroom practice (Hord & Loucks, 1980; Rutherford, 1986; Sparks, 1984). Teachers contemplating a change in classroom behavior need time to experiment, to interact with other teachers implementing similar changes, and to try out the new roles suggested by the innovation (Fullan, 1991). These teachers need support from their curricular reform leaders, colleagues, and administrators as they venture into uncharted territory. "Change is a process and . . . the facilitating of change entails continuous and systemic interactions" (Heck, Steigelbauer, Hall & Loucks, 1981, p. 8).

The Educational Leaders in the Mathematics (ELM) Project conducted by the SummerMath for Teachers Program at Mount Holyoke College researched the effects of their inservice program on a teacher's thinking and classroom practice. The inservice training was based on "recent research and theoretical work" (Simon & Schifter, 1991, p. 309). Participating teachers had completed a two week intensive summer workshop, had weekly classroom visits from ELM staff during the following school year, and attended an "advanced" workshop the next summer. Almost all of the teachers participating in the project adopted new classroom strategies for teaching mathematics. "More importantly, a significant number of the teachers came to base their instructional decisions on a view of learning as construction" (Simon, & Schifter, 1991, p. 328).

The Mathematics Curriculum and Teaching Program (MCTP) in Australia has also been successful in helping teachers change their classroom practice. They emphasize the importance of allowing the teachers opportunities to experiment.

> The evidence is overwhelming that teachers must have the benefit of time to reflect on the MCTP approach and to use it in their schools, and to interact with school colleagues if real change is to take place in mathematics teaching. (Owen & Johnson, 1987, p. 8)

The MCTP found that "one-shot" workshops seldom affected change in a teacher's classroom behavior. They noted that the most effective of the tested formats was a workshop which met at regular intervals during the school year enabling the teachers to try the suggested methodology in their classroom, then discuss the results at the next session.

Deborah Ball (1989) designed a teaching methods course which helped preservice teachers to view mathematics teaching and learning differently than they may have when they were students. The course presented mathematical content via constructivist pedagogy and then encouraged the teachers to reflect on their own thought and learning processes. Several of the prospective teachers stated that the course shifted their philosophy of teaching to the constructivist view. However, they found it easy to fall back to previously learned patterns, such as mainly teaching algorithms, when put in a classroom situation. Other researchers working with preservice and inservice teachers have had similar results (Davis, 1990; Schram, Wilcox, Lanier, & Lappon, 1988).

When the University of Massachusetts offered a general mathematics course based on student-centered group learning, they needed to prepare graduate teaching assistants to teach in that environment. A major part of the training involved learning how to use clinical interview techniques employed by psychologists. The teaching assistants tried to understand the students' thought processes rather than imposing their own perspective of a problem on the students. They commented on having to adjust their ideas about the best way to teach and learn mathematics (Konold, 1986).

These research projects have shown that teachers' classroom behavior as well as their teaching philosophy can be impacted. The Research and Development Center for Teacher Education in Austin, Texas developed a structure for charting this impact. Seven different stages of concern about an education innovation were identified.

0: Awareness: Little concern about or involvement with the innovation is indicated.
1: Informational: A general awareness and interest in learning more detail about it is indicated. The person seems to be unworried about himself/herself in relation to the innovation.
2: Personal: Individual is uncertain about the demands of the innovation, his/her inadequacy to meet those demands, and his/her role with the innovation.
3: Management: Attention is focused on the processes and tasks of using the innovation and the best use of information and resources. Issues related to efficiency, organizing, managing, scheduling, and time demands are utmost.
4: Consequences: Attention focuses on impact of the innovation on students in his/her [teacher's] immediate sphere of influence. The focus is on relevance of the innovation for students, evaluation of student outcomes, including performance and competencies, and changes needed to increase student outcomes.
5: Collaboration: The focus is on coordination and cooperation with others regarding use of the innovation.
6: Refocusing: The focus is on exploration of more universal benefits from the innovation, including the possibility of major changes or replacement with a more powerful alternative. Individual has definite ideas about alternative to the proposed or existing form of the innovation. (Newlove & Hall, 1976, p. 12)

These stages were identified as the result of research conducted by Hall and Rutherford (1976) on the stages of concern experienced by teachers who were attempting to implement team teaching. The study established the usefulness of the stages-of-concern model and reported that teachers' concerns progressed through different stages as they gained more experience with an innovation. Using the seven stages to compare a teacher's responses to open-ended questions about an educational innovation suggests the degree to which that teacher has "adopted" the innovation. Educational reform leaders would like all of the participating teachers to express stage 6 concerns. However, higher level concerns cannot be imposed by educational reform leaders or teacher educators. "Having concerns and changes of concerns is a dynamic of the individual. The timely provision of affective experiences and cognitive resources can provide the grist of concerns arousal and resolution, thereby facilitating the development of higher level concerns" (Newlove & Hall, 1976, p. 9). Similar to the constructivist methodology suggested for the classroom, teachers need to be provided opportunities to construct their own understanding of innovations, like student-centered learning, and their ramifications for the classroom.

## Summary

The constructivist theory of knowledge has been a central theme in this review of literature. It holds that all knowledge must be personally constructed. It is a theory which is currently embraced by many mathematics educators as a good explanation of how students learn mathematics. If a teacher accepts the theory as a basis for teaching, his or her classroom interactions must become more student-centered. They must be structured to assist the students in constructing their own mathematical knowledge. This represents a change in behavior for many high school mathematics teachers. Helping teachers make this change involves helping them construct their own understanding of the pedagogy much as they will help their students construct understandings of mathematics.

# METHODOLOGY

## Theoretical and Conceptual Framework

Teacher-student interactions have been studied for many years; however many of these studies were only interested in recording with whom the teacher was interacting and how often. For example, Ned Flanders devised a coding scheme for classifying classroom observations (Amidon & Flanders, 1967). The coding scheme consisted of recording, at preset intervals (usually every three seconds), the type of interaction taking place. Interactions were classified in six or seven categories such as teacher lectures, teacher criticizes student(s), teacher praises student(s), teacher asks questions, student responds, student asks question, and silence or confusion. Analysis was then done on type, frequencies and order of interchanges occurring, thereby providing a picture of the dynamics of the classroom. Because of the use of broad categories, this system gave little insight into the quality of teacher-student interactions, and a recent study suggested that the quality of interactions is more important than even the amount of time given to instruction (Reimers, 1991).

Presently, some researchers are looking at teacher-student interactions in a more qualitative manner using audio- and/or videotapes of the classroom, teacher diaries, and interviews with teachers and students. Findings are interpreted with an emphasis on a holistic perspective. Descriptions of classroom settings along with a more detailed categorization of teacher-student interactions provide a more complete picture (Kouba, 1991; Mehan, 1982; Reimers, 1991; Renninger, 1985; Sikka, Tedder & Ewing, 1991). Consequently, qualitative research strategies were selected to structure this study of teacher-student interactions.

The following five characteristics of qualitative research, listed in Qualitative Research For Education by Bogdan and Biklen (1992), further indicate the appropriateness of qualitative research for a study of classroom interactions.

1. The natural setting is a direct source of data and the researcher is the key instrument. Much of the data for this study was collected in the classroom and supplemented by an understanding that was gained from the researcher observing the events rather than just looking at an outcome.

2. Qualitative research is descriptive. To accurately represent the complexity of classroom interactions they must be described rather than just quantified. This research report used descriptions and quotations from transcripts of interviews, field notes, and transcripts of audiotapes to describe patterns of teacher-student interactions.

3. Processes or actions are often the subject of qualitative research rather than just final outcomes. This study looked at the

processes of teachers and students interacting in instructional situations in mathematics classes.

4. Qualitative data are usually analyzed inductively. Patterns of interactions were drawn from the field observations and transcripts of interactions, rather than starting from an hypothesized pattern and trying to prove or disprove it.

5. "The ways different people make sense out of their lives" (p. 32) is a concern of the qualitative approach. Qualitative research can be helpful in studying teachers as they try to make their own "sense" out of an educational reform program such as the Systemic Initiative for Montana Mathematics and Science (SIMMS) Project.

Qualitative data collection is often done during contiguous site visits; however, limitations due to geographic distance between locations and other demands on the researcher's time made this impossible. "The goal of sampling is to get a representative view of individuals behavior and habitat" (Jacob, 1987). Intermittent site visits can satisfy this requirement. Firestone & Dawson (1981) even spoke of some benefits of intermittent visits.

> They make it possible to build rapport with respondents. . . . There is more opportunity to learn about facets of school life that are normally kept from strangers. Second, there are numerous opportunities to observe a variety of settings over an extended period of time (p. 21).

Consequently, the intermittent site visit approach, in spite of its interrupted observations, can be an acceptable observation strategy in documenting teacher-student interactions.

After data has been collected, it must also be presented in some effective format. Qualitative data can sometimes be effectively presented in a quantitative style. Evelyn Jacob (1987), a researcher from George Mason University, illustrated one such strategy which is often used by ecological psychologists. It produces detailed, objective descriptions of naturally occurring behavior that are amenable to quantitative analysis. There are three stages in conducting such a study: recording the stream of behavior, dividing the stream into behavior units, and analyzing the units. (Jacob, 1987)

> The most frequently used method for analyzing specimen records is based on the identification in the records of goal-directed actions of either the subject being observed or of other persons who are acting toward the subject. . . . The final step is describing the units' properties quantitatively. (Jacob, 1987, p. 7)

Erickson & Mohatt (1982) used this strategy when studying the classrooms of one Native American and one Caucasian teacher. They videotaped the classes for a total of 12 hours and from these tapes analyzed a variety of teacher and student behaviors. The data was presented with statements about the relative frequency of various behaviors. "One advantage of . . . a quantitative presentational style is that it provides the reader with a somewhat clearer picture of the magnitude of differences noted that completely qualitative data wouldn't give" (Schofield & Anderson, 1984, p. 25).

This study used the quantitative presentational style described above as one way to report on the teacher-student interactions captured on the audiotapes. The qualitative data from class observations and teacher interviews put the resultant figures in a context, showing a more complete picture of the classroom interactions than either form would give alone.

## Selection of Teachers for Study

The teachers for this study were selected from among the nine people who were observed and interviewed prior to the 1992 SIMMS Summer Teacher/Leader Institute. Those considered also had to be pre-piloting the full Level One SIMMS program during the 1992-1993 school year. Since all the institute teachers had undergone an extensive screening, the only other factors used for selection were school size, geographic location, participation in a pre-summer interview, and gender. Five teachers were selected, but one was later dropped due to family problems. Each of the four teachers selected had at least eight years of teaching experience and had taught most of the traditional high school curriculum. Two teachers were women, and two were men.

Diversity of geographic location was considered, within the limitation of the researcher's ability to visit each location several times. One of the research sites was a large high school, enrollment of about 1,700, located in a city with an area population of 55,000. The teacher selected at that school, who will be identified as Adam, was one of 12 people teaching in the mathematics department. The second site was a single-industry town with an area population of approximately 3,500. The high school had an enrollment of 500, with approximately 20% American Indian students. The teacher, who will be called Carol, was one of four mathematics teachers in the school. The other two research sites were ranch/farm communities. One, a community of about 1,400, had one school, the high school portion of which enrolled about 100 students. The teacher, who will be called David, was one of two mathematics teachers. These teachers taught grades 7-12. The other site had a school with an enrollment of about 200 students which drew from an area of approximately 3,000 people. The teacher, Betty, was one of two mathematics teachers in the school. A classroom profile of each teacher appears at the beginning of the next chapter.

## SIMMS Teacher Preparation

The 1992 SIMMS Teacher/Leader Institute was held to prepare teachers to participate in field testing the SIMMS program. The institute met seven hours a day, five days a week for six weeks. The 32 teachers who attended were chosen from a pool of over 100 applicants. They were selected on the basis of the quality of recommendations, teaching experience, leadership potential, geographic distribution, and gender.

The institute presented the teachers with an opportunity to experiment with different types of technology and instructional structures. The goals of the institute were to

- prepare teacher/leaders to teach the SIMMS integrated mathematics materials using advanced technology where appropriate;
- provide an environment in which teachers can examine and question their beliefs about mathematics, teaching and learning;
- develop a statewide network of teacher/leaders to provide inservice in the use of SIMMS materials;
- provide teacher/leaders with an intensive summer experience teaching SIMMS materials to American Indian youth with attention to gender equity issues; and
- prepare teacher/leaders to promote the use of a statewide telecommunications network using a variety of modalities. ([SIMMS], 1992b, p. 1)

To reach these goals the institute leaders provided opportunities for the teachers to work through sample SIMMS modules, much as their students would during the school year. There were opportunities to teach selected parts of the modules to American Indian students who were attending a four-week mathematics workshop at the same location. These and other teaching situations were discussed after being observed in person and/or on videotape. Ways of interacting with the students as they worked in groups or as a whole class were discussed.

During the sessions on technology, cooperative learning and SIMMS philosophy, the leaders of the institute and visiting consultants tried to modeled the facilitator of learning role the teachers would be expected to assume. Other professional growth opportunities were provided in terms of participating in cooperative learning groups, practicing writing, and confronting gender and ethnicity equity issues. All participants were encouraged to use personal journals to reflect on proposed changes. With permission of the participants, the researcher read the journals and shared summaries of the entries with other SIMMS personnel. The information was used to tailor the institute to the needs and interests of the participants.

The teachers also designed informational presentations on the SIMMS project for their colleagues, administrators and community. These presentations were given during the pre-piloting year to their schools and communities to acquaint people with the long- and short-term goals of the SIMMS project for high school mathematics students.

## Statement of Researcher Bias

It was the researcher's position that patterns of teacher-student interactions would not differ significantly between a teacher's SIMMS and non-SIMMS classes. No specific interactions were anticipated, just consistency in a teachers' general pattern of interactions. The way teachers interact with their students was thought to be a product of their beliefs about mathematics teaching and learning, and habits of teaching, not a product of the curriculum.

Experienced teachers have often established a pattern of classroom behavior which gives the "desired results." Now the NCTM is trying to change the nature of those "desired results" and this requires a change in teacher behavior. Many teachers outwardly embrace these new ideas, but often do not translate them into changed classroom behavior. While the SIMMS program may make it easier for the teacher to assume new roles, such as facilitator-of-learning, it does not necessarily produce a change.

Association with the SIMMS project and the review of current literature in mathematics education influenced the researcher's views on appropriate teacher-student interactions. Since completing this study and returning to college teaching, the researcher has attempted to implement the interactions described in the facilitator of learning description. Finding an appropriate balance between student-centered and teacher-centered interactions is an on going challenge.

## Data Collection

Data for the study were collected by the researcher during the fall semester of the 1992-1993 high school year. During September, classroom observations, videotaping and audiotaping techniques were tested and refined. The Flanders Interaction Coding Scheme was tested and abandoned because it was difficult to hear small group teacher-student interactions without standing right next to the teacher, and it was felt that the students did not interact normally under those conditions. Audiotape recording of the classroom dialogue was selected for documentation of teacher-student interactions. This permitted the use of more detailed interaction categories.

Data collection visitations started in October. Each teacher was visited three times with five weeks between visits, the final visit occurring in January. Classroom observations and audiotapes of teacher-student interactions were made on two consecutive days in one SIMMS class and one non-SIMMS class. Selection of which SIMMS and which non-SIMMS classes to include in the study was made on the basis of teachers' schedules; similarity of level, when possible, of non-SIMMS class; and effective use of researcher's time. The selected non-SIMMS classrooms were not ninth-grade classes because the teachers in the study taught the SIMMS program to all of their ninth-grade students. Non-SIMMS classes observed included eighth grade mathematics, geometry and algebra/trigonometry.

All observed classes were audiotaped. Most often, the teachers wore a small tape recorder attached to a belt, or placed in a shirt pocket during the observed class period. One teacher did not like to wear the recorder and, on occasion, asked that the recorder be placed on a table at the front of the room. This was done except when the class was engaged in group work and there was a need to record individual teacher-student interactions.

The researcher had been introduced to the students during the September preliminary visits. The students were informed that the purpose of the upcoming repeated visits was to observe the way the class is run and that neither teacher nor students were being "graded." During subsequent visits, the researcher was generally ignored by the teacher and students. During whole class instructional situations, the researcher observed from the back or side of the classroom and took notes on classroom activities. The researcher walked around the room during group work, noting student activities. An effort was made not to be near the group which the teacher was assisting, thereby obtaining an audiorecording of a more "usual" interaction between teacher and student(s).

In order to provide some additional views of the classrooms under study, teachers videotaped the classes during the week in which the observations were done. Most of the students appeared to forget about the video camera, but a few did not like it and asked that it to be focused on a different group. Generally, it did not disrupt the usual flow of the classes.

Teachers were interviewed during each of the three site visits, each interview lasting from 30 minutes to an hour. An interview guide (see Appendix A) was used. The researcher who works with an interview guide must allow for the possibility that what interested the other teachers interviewed may be of little interest to the teacher currently being interviewed (Seidman, 1991). Consequently, while all teachers were asked basically the same questions, follow-up questions varied, as the teachers talked about their experience pre-piloting the SIMMS materials.

All teachers who participated in the 1992 Summer Institute met for two-day conferences during the 1992-1993 academic year, in October, January, and April. The purpose of the meetings was to provide another avenue of support, allow the teachers to exchange ideas, provide inservice opportunities for new ideas, and obtain feedback for SIMMS administrators on the progress of the pre-pilot. These meetings were used as informal data gathering opportunities during both formal meetings and social gatherings.

## Multiple Data Sources

Multiple forms of data were used to document the teacher-student interactions. Each form had a specific purpose, but all worked together to support findings. The field notes taken during classroom observations were used to describe the general characteristics of the classroom, such as physical setup, different types of learning situations, and their duration. Transcripts of audiotapes were used to examine teacher-student verbal exchanges. Videotapes of observed classrooms supplemented field notes and helped determine general characteristics of a given classroom and provide a "before" and "after" view of observed lessons. Transcripts of teacher interviews provided information on the teacher's interpretation of classroom interactions.

## Description of Transcript Coding

Detailed transcripts were made of the audiotaped class sessions. Only *instructional time* was used for analysis. All teacher-student dialogue concerning disciplining of students or administrative tasks, such as taking roll and reading announcements, was deleted. All time during which students were taking pencil and paper tests was also not included. The transcripts were then partitioned into separate teacher-student interactions. An interaction was defined as a dialogue between teacher and class or teacher and student(s). A new interaction was delineated when the nature of the exchange no longer fit the category being used.

The facilitator-of-learning description generated for this study (see page 8) was used as a preliminary coding schema. Additional codes were added to the list as interactions were encountered which did not fit the existing categories. After approximately one third of the transcripts had been reviewed, a final list of codes was established and all transcripts were re-coded. The final list of the codes follows below.

The teacher:

2. assists students in organizing cooperative learning groups;
3. has students do class presentations;
6. demonstrates use of appropriate technology to help solve problems;
7. encourages students to use appropriate technology to help solve problems;
8. requires students to express mathematical ideas in written and oral form;
10. encourages discussion among students about problems and possible solutions;
11. attempts to understand student's rationale for his/her work;
12. brings up evidence that conflicts with a student's interpretation so student can reexamine his/her thinking;
13. asks process-oriented questions;
14. asks open-ended questions;
15. moderates discussions on student generated ideas;

16. helps students to rely on themselves to determine whether something is mathematically correct;
18. asks judgment questions;
di. uses direct instruction;
ra. reads (or has student read) answers to assignment from answer book;
sa. asks short answer questions;
sr. has students report on group work;
ta. helps with the mechanics of the calculator or computer; and
td. gives general directions on how to proceed with the work.

A more complete description of the codes and the situations in which they were used may be found in Appendix B.

The following are a few of the more frequently used codes and situations in which they were used.

*10: Encourages discussion among students about problems and possible solutions:* Teacher does not immediately pass judgment on suitability of problem solution, but allows students to consider possible alternatives.

*13: Asks process-oriented questions:* Teacher's questions focus on the way a problem is solved more than on the solution. The code was also used when a teacher asked which algorithm was appropriate in a given situation.

*14: Asks open-ended questions:* Teacher's questions are open to interpretation and/or do not have an expected response.

15: *Moderates discussions on student generated ideas:* Teacher invites other students to comment on ideas which were generated by students.

*di:* *Uses direct instruction:* Teacher assumes authority by either providing information about the topic, demonstrating an algorithm, or telling students their answers were correct.

*sa:* *Asks short answer questions:* Questions from the teacher have an expected short answer and teacher passes judgment on correctness of that answer.

The number codes were derived from the interaction's position in the facilitator-of-learning description. The code numbers are not sequential because some of the facilitator characteristics could not be assigned to a single classroom interaction and were eliminated from the coding list. Letter codes were assigned to those interactions which were added to the coding list. Interactions initiated by a student question were marked with an "sq" preceding the interaction code.

If both number and letter codes fit an interaction, the number code was given precedence. If two numbers fit an interaction, the higher number was used. Preliminary use of the Flanders coding schema influenced the decision to use a single code for each instruction.

While this coding system makes use of categories similar to those used by Flanders, it is different in application. Flanders' interaction coding system used general categories and required the researcher to make a judgment on the spot as to the nature of the interaction. The system used for this study allowed more specific categories of interactions and permitted the researcher time to consider the most appropriate category for a specific interaction.

A computer database was created from the coded data. Each database record included a transcript identification number, the text of the interaction, the assigned code, the length of the interaction in characters, a classification as to whole class or small group situation, and a sequence number. Small group interactions were defined as those occurring between the teacher and from one to four students.

The reports generated from the transcripts were as follows:
a) full classroom transcript of all instructional interactions;
b) coded database version of classroom transcript;
c) summary of codes in a classroom transcript;
d) summary of codes from all transcripts from an individual class;
e) summary of codes from all SIMMS class transcripts;
f) summary of codes from all non-SIMMS class transcripts.
All summaries included calculation of the percentage of instructional time (see page 38) spent in each type of interaction and the percentage of instructional time spent in whole class instruction.

## Validation

Each teacher in the study previewed their classroom profiles and summaries of coding of their classes' transcripts and the composite classes. All of the teachers found the profiles to be accurate after minor modifications. The transcript analysis prompted questions about exactly which interactions were being summarized and compared. Most expressed some surprise at the results but, after studying the coding categories and discussing their use, agreed the findings were representative of their teaching. The videotapes taken on non-visiting days confirmed that observed classes were generally typical class sessions.

The goal of the interview is to understand how the participants understand and make sense of their experience. If the interview structure allows participants to explore their feelings in a way that makes sense to them as well as to the interviewer, then it has gone a long way toward validity (Patton, 1990).

The interaction coding schema was reviewed by two different professors of education. They were each given a list of the codes and an explanation of the way they had been used. Both reviewers worked independently on the sample pages from two different transcripts. The same character count strategy which was used in quantifying the teacher's interaction formed the basis for the following comparison. Since the analysis of the transcripts was done on the basis of student-centered and teacher-centered interactions, comparison of these categories rather than individual "codes" was used. Both of the reviewers and the researcher agreed on the coding of student-centered or teacher-centered interactions, on 50% of the transcript samples. The researcher agreed with one of the reviewers on about 60% of the sample transcripts and with the other one on about 80% of the sample transcripts. Discussion with the reviewers after they completed their coding showed the difficulty of categorizing classroom interactions from written transcripts only. In spite of being briefed on the classroom scenario, the reviewers interpreted some situations quite differently from each other and the researcher. If the reviewers had been able to see a videotape of the sessions transcripted they may have coded it differently. As noted in the first characteristic of qualitative research (see page 27), observation of an event gives added information not available in its purely written form.

# FINDINGS

## Teacher Profiles

The four teachers in this study will be identified as Adam, Betty, Carol, and David. They are all experienced teachers and have taught all levels of high school mathematics. The teachers came into the Systemic Initiative for Montana Mathematics and Science (SIMMS) project knowing very little about it, except that it was a multi-million dollar joint undertaking of the National Science Foundation (NSF), Montana Council of Teachers of Mathematics (MCTM) and the State of Montana. They knew SIMMS was attempting to improve mathematics education in Montana and they wanted to be part of that effort. All of the teachers are members of MCTM. Three of them had participated in another program funded by NSF and sponsored by the MCTM entitled Integrating Math Programs And Computer Technology (IMPACT).

The following profiles describe each of the four teachers in the study. Comparisons were made between each teacher's non-SIMMS and SIMMS classes as to the physical classroom setting, technology usage, and general teacher-student interactions. An understanding of a teacher's classroom situation is essential when trying to interpret interaction patterns.