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Changes in Curricula Design and the Effect on Transfer of Learning in Remedial Mathematics Students

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To the Graduate Council:

I am submitting herewith a dissertation written by Gladys Hayes Crates entitled "Changes in Curricula Design and the Effect on Transfer of Learning in Remedial Mathematics Students." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Education, with a major in Educational Administration.

Norma Mertz, Major Professor

We have read this dissertation and recommend its acceptance:

Mary Jane Connelly, Phyllis Huff, Steve Kuhn

Accepted for the Council:
Dixie L. Thompson

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

To the Graduate Council:

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Norma T. Mertz

Dr. Norma Mertz, Major Professor

We have read this dissertation
and recommend its acceptance.

Mary Jane Connelly

Dr. Mary Jane Connelly

Phyllis E. Huff

Dr. Phyllis Huff

Stephen W. Kuhn

Dr. Steve Kuhn

Accepted for the Council:

C W Minkel

Associate Vice Chancellor
and Dean of the Graduate School

CHANGES IN CURRICULA DESIGN AND
THE EFFECT ON TRANSFER
OF LEARNING IN
DEVELOPMENTAL MATHEMATICS STUDENTS

A Dissertation

Presented for the

Doctor of Education

Degree

The University of Tennessee, Knoxville

Gladys H. Crates

May, 1994

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ABSTRACT

The purposes of this study included examination of curricular and instructional integration of mathematics and the sciences in a basic mathematics/elementary algebra course to see if it would (1) result in greater achievement in mathematics, (2) result in greater achievement in chemistry, (3) encourage transfer of learning from mathematics to chemistry, (4) result in more positive attitudes towards mathematics, and (5) would lessen anxiety levels towards mathematics. This study, conducted at Chattanooga State Technical Community College during the 1991-92 academic year, used a control/experimental design. Students who expressed an interest in nursing or another allied health field requiring basic chemistry, and who were required to enroll in a basic mathematics/elementary algebra course, were enrolled in one of two designated mathematics sections taught by the researcher. Students who completed one of these designated sections during the 1991 fall semester and who completed basic chemistry during the 1992 spring semester became the subjects of the study.

The control group was taught using a traditional approach, with no particular steps being taken to integrate mathematics and science and without the use of the calculator. The experimental group was taught with a

curriculum designed to use the calculator extensively and to encourage integration of mathematics and science.

In order to determine whether the results were statistically significant, analyses of the date were made using the Student's t distribution. No difference in achievement in either basic mathematics or basic chemistry was found between the control and the experimental groups; nor was any difference in attitude concerning mathematics and in anxiety levels about mathematics found between the two groups. By the end of the semester, both groups did show a significant decrease in anxiety level towards mathematics. The hypothesis regarding transfer of mathematical skills from basic mathematics to basic chemistry could not be examined because there was not a large enough sample remaining after attrition during the semesters to provide for statistical analysis.

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CHAPTER I

INTRODUCTION/BACKGROUND/CONTEXT

In the last decade, numerous books and reports have decried the overall academic preparation of American students, including <u>A Nation at Risk: The Imperative for Educational Reform</u> (National Commission on Excellence in Education, 1983), <u>The Closing of the American Mind</u> (Bloom, 1987), and <u>Cultural Literacy</u> (Hirsch, 1988). A particular area of concern has been the lack of achievement in mathematics and the sciences (Byrne, 1989b; Dossey, 1990; Educational Testing Service, 1989b; George, 1983; Lindquist, 1989; McKnight et al, 1987; National Center for Education Statistics, 1992; National Research Council, 1984; National Research Council, 1990; Powell, 1989; Worthy, 1986). Mean mathematics scores on the Scholastic Achievement Test (SAT) have dropped from 502 (out of a possible 800) in 1963 to 474 in 1991. Comparative studies cited in (Pyko, 1987) and (Steen, 1987) show that a typical student in the United States achieves far less in mathematics and the sciences than the typical student in other industrialized nations. The Educational Testing Service (1989a) presented a gloomy view of United States education with the release of <u>A World of Differences</u>, an international comparison of 24,000 13-year olds in the United States, Ireland, Spain, South Korea, the United Kingdom and four Canadian provinces. American students placed last in mathematics and almost last in science.

One of the possible reasons cited in these reports for this lack of achievement in mathematics is the way in which mathematics is being taught in the United States (Powell, 1989). The National Council for the Teachers of Mathematics has proposed that fruitless repetition of classroom material is a major flaw in mathematics instruction: "The villain ... is an approach to math teaching that is out of date and mired in pointless pencil-and-paper computation, rote memorization, and multiple-choice tests" (Byrne, 1989a). According to the International Association for the Evaluation of Education Achievement, the teaching of mathematics is "predominantly formal with an emphasis on rules, formulas, and computational skills as opposed to being informal, intuitive, and exploratory" (Bennett, 1986).

Mathematical instruction presently seems to be a matter of rote learning of facts and formulas rather than logical reasoning. Students are often left with sets of discrete knowledge rather than with the ability to apply methods of problem solving and thinking skills to similar situations in other subjects. Three recent reports on K-12 mathematics - Everybody Counts: A Report to the Nation on the Future of Mathematics Education (National Research Council, 1989), Curriculum and Evaluation Standards for School Mathematics

(National Council of Teachers of Mathematics, 1989), and A World of Differences (Educational Testing Service, 1989a) emphasize reasoning over rote learning and using applications in mathematics classes as a way to stem the tide of declining mathematical ability and interest.

As has already been cited, science achievement as well as mathematics achievement is declining in the United States. A good foundation in mathematics is deemed essential to the successful study of chemistry and physics (Berryman, 1983; Menis, 1987; Steen, 1987). The results of a survey Menis conducted among chemistry teachers in 1981 indicated that students had difficulties solving chemistry problems where command of mathematics concepts was essential. Steen (1987) wrote that "since mathematics is the foundation discipline for science, the state of mathematics education is a crucial predictor of future national strength in science and technology" (p. 251). (Bent, 1970) found that the severest difficulties among students during final exams in thermodynamics were in basic mathematical procedures; chemistry students were unable to deal with mole fractions only because they could not solve simple equations (Myers, 1983). Because these science students had not mastered basic mathematical procedures, they could not succeed in their science courses supporting the contention throughout the literature that achievement in the sciences is inexorably tied to achievement in mathematics.

Students interested in careers in such high-demand and varied fields as allied health, nursing, and chemical and engineering technology are required to take chemistry. Teachers' comments have indicated that many chemistry students are unable to handle basic mathematical concepts involving ratio and proportion, percentages, formulas, linear equations, exponents, conversions, significant digits, and calculations in scientific notation. Many students have indicated that they like the chemistry, but dislike the mathematics. They do not see mathematics as an integral part of chemistry. Consequently, one of two things happens: (1) teachers must take time to reteach mathematics as it relates to chemistry, or (2) teachers tell students that they cannot cover mathematical topics that students should already know. Comments from students at Chattanooga State Technical Community College indicate that many of them become frustrated and either withdraw from chemistry and change their career plans or make low grades in chemistry because they are unable to transfer skills learned in mathematics to chemistry.

Studies such as those by Menis (1987) and Steen (1987) as well as interviews by the researcher with science teachers and students suggest that many students see mathematics introduced into a science class as an unwelcome intrusion or diversion from the main subject matter. That is, students do not see the essential connection between mathematics and science. Indeed, Myers (1983) has written in regard to students' lack of mathematical understanding and problems confronting science education: "... the teaching of mathematics remains pretty much a dismal failure" (p. 121). In fact, various studies (Arons, 1983, 1984a, 1984b; Bent, 1979; Bunce and Heikkinen, 1986; Champagne and Klopfer, 1982; Hudson and McIntire, 1977; Liberman and Hudson, 1979; Menis, 1987) have linked the ability to master science material to the ability to solve mathematical problems in science courses. In other words, difficulties with mathematics and science achievement may be reflections of the same problem.

Integration of science and mathematics is common practice in most developed countries (Pyko, 1987), although it is not a common practice in the United States, where mathematics and science are seen as discrete subjects. This integration of the two subjects in the curriculum is a possible reason for the higher achievement in other countries. Therefore, a potential way to improve both mathematics and science achievement in the United States is to alter the mathematics curriculum and the way in which the mathematical material is presented to the students so that integration of the two subjects is obvious and transfer of learning from mathematics to science is achieved.

Recently, interest has been shown in integrating instruction in mathematics and science in this country. Indeed, in "Mathematics Education: A Predictor of Scientific Competitiveness," Steen (1987) stated as a goal:

> Mathematics in the schools should be linked to science in the schools. To achieve this goal science teachers must actually use mathematics, mathematics teachers must use science, and mathematics and science teachers must discuss coordination of their teaching. (p. 302)

The integration of the two subjects is desirable because concepts from mathematics are essential to understanding science. A term used to describe this process is "transfer of learning." Menis (1987) defined transfer as

> the psychological term for the ability to utilize concepts from one area, for example, mathematics, in dealing with a second area, such as chemistry. It is the ability to combine basic concepts or principles, and then apply them to a variety of problems. (p. 105)

Milton (1971) reflected that the issue of transfer of learning was exceptionally complex and that one of the crucial questions was: "What learning circumstances or conditions maximize the chances that generalization or transfer will occur?" (p. 6) He went on to say that transfer "does not occur automatically; a student does not generalize solely by virtue of having studied a particular subject or discipline" (p. 6). Menis (1987) designed a study to discover whether or not automatic transfer across disciplines from mathematics to chemistry was occurring. He found that tenth grade Israeli students showed success rates of only 30.6% to 49.4% in transferring mathematical skills concerning isolation of variables, proportions, and percentages.

If we accept "transfer of learning" as an actual psychological process, but one that is not automatic, then it follows that curriculum and instruction designed to encourage transfer between related subjects such as mathematics and the sciences should result in higher achievement in both areas. Declining achievement in mathematics and the sciences suggests that such transfer of learning is not currently being encouraged. Educators need to know if curriculum with instruction tailored to integrate these two subjects, rather than one which treats them as discrete, unrelated subjects, can, in fact, encourage the transfer of learning from mathematics to a science and improve achievement in both.

Statement of the Problem

Achievement in both mathematics and the sciences has been declining. Since the ability to perform mathematical operations is required to solve problems presented in science courses such as chemistry and physics, achievement in science is tied to achievement in mathematics. Current curricular design and instructional strategies in mathematics are not producing students who can transfer skills from the mathematics classroom to the science classroom, even if those students have demonstrated in the mathematics classroom that they can perform the requisite mathematical procedures. Transferring the skills learned in mathematics to the sciences, specifically chemistry, is difficult for many students. Although current reports advocate the integration of mathematics and science in the respective courses, we do not know if integration of the two subjects in instruction will enhance the possibility for greater mathematics and science achievement and transfer. This study examined this possibility.

Purpose

The purposes of this study were to examine if curricular and instructional integration of mathematics and the sciences leads to increased transfer of learning from mathematics to chemistry as well as greater achievement in mathematics and chemistry. Since the chemistry teachers expect their students to use calculators, the researcher taught students in the experimental group to use calculators and allowed them to be used on tests. Students in the control group were not instructed in calculator usage and were not allowed to use them on tests. The study compared achievements in mathematics and chemistry as well as transfer of learning from mathematics to chemistry for students taught algebra and basic mathematics in two different ways:

(1) with a curriculum designed to use the calculator extensively and to encourage integration of mathematics and the sciences and, therefore, transfer of learning from mathematics to chemistry, and

(2) with a traditional approach, with no particular steps being taken to integrate the subjects and without use of the calculator.

Using an experimental design, the study determined what effect, if any, a basic mathematics/elementary algebra course designed to use a calculator extensively and to integrate mathematics and science had on mathematics achievement, on chemistry achievement, and on the transfer of mathematical skills and problem solving ability to a subsequent chemistry course as reflected in student test results. As well as studying student achievement in mathematics and chemistry, the researcher was interested in student perceptions towards mathematics as reflected by student replies to surveys designed to measure anxiety levels and attitude about mathematics.

The hypotheses to be tested were:

(1) Achievement in basic mathematics and elementary algebra will be greater for students who complete an experimental basic mathematics/elementary algebra course designed to use a calculator extensively and to

integrate mathematics and science than for students who complete a traditional basic mathematics/elementary algebra course.

(2) Achievement in basic chemistry will be greater for students who complete an experimental basic mathematics/elementary algebra course designed to use a calculator extensively and to integrate mathematics and science than for students who complete a traditional basic mathematics/elementary algebra course.

(3) Transfer of mathematical skills for selected isomorphic topics in basic mathematics/elementary algebra and basic chemistry will be greater for students who complete an experimental basic mathematics/elementary algebra course designed to use a calculator extensively and to integrate mathematics and science than for students who complete a traditional basic mathematics/ elementary algebra course.

(4) Attitudes concerning mathematics will be less negative for students who complete an experimental basic mathematics/elementary algebra course designed to use a calculator extensively and to integrate mathematics and science than for students who complete a traditional basic mathematics/elementary algebra course.

(5) Anxiety levels for mathematics will be lower for students who complete an experimental basic mathematics/elementary algebra course designed to use a

calculator extensively and to integrate mathematics and science than for students who complete a traditional basic mathematics/elementary algebra course.

Methods and Procedures

An experimental study was conducted at Chattanooga State Technical Community College during the 1991-92 academic year to test the hypotheses stated above. Using four mathematical topics essential for success in basic chemistry, an experimental mathematics curriculum was designed, matching these mathematical topics with appropriate applications suggested by science teachers at Chattanooga State.

Students who expressed an interest in nursing or another allied health field requiring CH104, Principles of Chemistry, and who were required to enroll in MA070, Basic Mathematics/Elementary Algebra, were identified during fall orientation sessions. They were encouraged to enroll in one of two designated mathematics sections taught by the researcher. One section of MA070 was used as the control group and the other as the experimental group. The students who completed one of the two designated sections of MA070 during the 1991 fall semester and who completed CH104 during the 1992 spring semester became the subjects of the study.

This study contrasted two types of curriculum perspectives. Both the control and experimental groups used a popular traditional text (Keedy and Bittinger, 1988). The control group was taught using this textbook as the sole curriculum resource. The material was presented to them as it appeared in the textbook, stressing mathematical procedures instead of applications, and without using calculators as an integral part of the class. The experimental group was taught using the same textbook; however, students received supplementary material containing applications suggested by instructors in chemistry, anatomy and physiology, nutrition, and pharmacology. Applications were used to motivate the desire to learn mathematical procedures. The researcher integrated mathematics and science whenever possible, using the calculator as an integral part of the class.

Four types of data were collected, using a series of individual paper and pencil tests in a control/experimental research design: achievement in mathematics, achievement in chemistry, transfer from mathematics to chemistry, and student perceptions about mathematics. These data were statistically analyzed to see if there were any differences in achievement in mathematics and chemistry, transfer from mathematics to chemistry, and student perceptions between the control and the experimental groups. In order to determine whether the results were statistically significant, analyses were made using the Student's t distribution.

Significance

Although individuals in professional journals and at professional meetings have suggested that integrating mathematics and science will improve students' comprehension and achievement in both subjects, there have been few empirical studies to examine this proposition. This study examines whether, indeed, integration of such subject matter can improve comprehension and achievement in both subjects in a test group. Further, though by necessity science teachers often teach mathematics within the context of their science courses, there has been little experimentation with integrating science into a mathematics curriculum. This study examines whether such integration of science into a mathematics course can encourage comprehension and achievement in both chemistry and mathematics. Furthermore, the term "transfer of learning" represents an important educational concept, but we have only a small base of knowledge about what kinds of curricular design and instructional methods encourage transfer. Specifically, this study establishes a base of knowledge by examining if an integrated curricular design and instructional methods designed to achieve transfer can enhance achievement in both mathematics and chemistry as well as transfer of learning from mathematics to chemistry. Thus, this study empirically examines three issues that have confronted mathematics and science education for years.

To further clarify these issues, this study and replications of it could become a basis for improving mathematics instruction as it affects chemistry. Identifying instructional strategies that improve mathematics achievement and transfer of mathematical skills should, when such strategies are implemented, result in improved achievement in chemistry. This knowledge could become a basis for redesigning mathematics teaching. This study should provoke similar studies of mathematics and science integration at different levels of mathematics instruction, such as calculus to physics.

This study was a beginning step in examining and experimenting with strategies to improve student achievement in mathematics and chemistry and to encourage the transfer of learning from mathematics to chemistry. Therefore, this study was also a beginning step in clarifying strategies which could encourage transfer of learning in other areas as well.

Definitions

(1) AAPP Test - The **A**cademic **A**ssessment **P**lacement **P**rogram consists of a battery of tests used by the Tennessee Board of Regents schools to measure entry level skills in mathematics, reading, and English. Scores are used to determine mandatory placement in entry level courses.

(2) Transfer of Learning - Transfer of learning is the ability to apply concepts learned in one area, such as mathematics, to a variety of problems in another area, such as chemistry.

(3) Remedial Course - The Tennessee Board of Regents defines a remedial course as one whose course contents consist of material which is generally taught at the ninth grade level or below.

(4) Developmental Course - The Tennessee Board of Regents defines a developmental course as one whose course contents consist of material which is generally taught at the tenth through twelfth grade levels.

Assumptions

The assumptions underlying this study were:

(1) The Academic Assessment Placement Program (AAPP) used by the Tennessee Board of Regents schools measures

entry level mathematical skills and accurately places students into MA070, Basic Mathematics/Elementary Algebra. Therefore, students placed in MA070 have similar mathematical deficiencies and skills, and classes can be compared.

(2) Achievement in mathematics and science is linked.

(3) Mathematical achievement is measurable.

(4) Scientific achievement is measurable.

(5) Transfer of learning from mathematics to chemistry is measurable.

(6) Attitudes towards mathematics can be determined.

(7) Anxiety levels about mathematics can be determined.

(8) Students enrolled in Basic Mathematics/Elementary Algebra at Chattanooga State Technical Community College are typical of students who have not been successful in a college preparatory curriculum. Therefore, the results of this study can be generalized to other such students.

Limitations and Delimitations

(1) This study considered Chattanooga State students enrolled in MA070 in fall 1991 and subsequently in CH104 in spring 1992. The results of this study may not apply to other disciplines, colleges, or regions of the state or country.

(2) The results from the fall 1991 semester algebra classes may not be typical of other semesters.

Organization of the Study

The study is presented in five chapters. In Chapter I the study is introduced. The background of mathematics education is discussed, with particular emphasis on the concept referred to as "transfer of learning." Chapter I also includes a statement of the problem, a statement of the purpose of the study, a review of the methods and procedures, and a discussion of the significance of the proposed study. Finally, Chapter I concludes with the definitions and assumptions made in designing the study, the limitations and delimitations of the study, and the organization of the study.

Chapter II presents a review of related literature covering the general state of mathematics education in the United States, transfer of learning, and solutions proposed by various authorities. Chapter III presents, in detail, the design and methodology of the research project, and Chapter IV presents the findings of that research. The last chapter, Chapter V, summarizes the study, discusses the findings, and, finally, provides conclusions and recommendations for further research.

CHAPTER II

REVIEW OF THE LITERATURE

For the past decade, the state of education in the United States, and particularly the state of mathematics and science education, has been a topic of intense scrutiny. The literature in the field delineates the perceived problems of our current system of mathematics education and discusses recent efforts to remedy these problems. This chapter provides a review of that research and literature and of the concepts and literature underlying the study. It is presented in three sections. In the first, literature related to the general state of mathematics education is examined. In the second, transfer of learning is examined. In the third, strategies for addressing the identified problems in mathematics education are examined.

General State of Mathematics Education

Although there is little empirical research as to the reason, achievement in mathematics and science has continued to decline (Byrne, 1989b; Dossey, 1990; Educational Testing Service, 1989b; George, 1983; Lindquist, 1989; McKnight et al, 1987; National Research Council, 1984, 1990; Powell, 1989; Worthy, 1986). Mean mathematics scores on the

Scholastic Achievement Test (SAT) dropped from 502 (out of a possible 800) in 1963 to 474 in 1991. Comparative studies cited in Pyko (1987) and Steen (1987) show that a typical student in the United States achieves far less in mathematics and the sciences than the typical student in other industrialized nations. For example, mathematics achievement of the top 5% of American twelfth grade students is lower than that of students from other industrialized nations, with the average twelfth grade Japanese student outperforming 95% of comparable United States twelfth graders. Moreover, in 1985 United States eighth graders ranked thirteenth among seventeen countries in achievement in mathematics. The Educational Testing Service (1989a) presented a gloomy view of United States education with the release of A World of Differences, an international comparison of 24,000 13-year olds in the U.S., Ireland, Spain, South Korea, the United Kingdom and four Canadian provinces. U.S. students placed last in mathematics and almost last in science.

Although the Mathematical Association of America (MAA) and the National Council of Teachers of Mathematics (NCTM) released separate reports in 1980 urging curricular reform in mathematics, there was little support for educational change at that time; indeed, educational activities at the National Science Foundation were suspended in 1980. Most of the problems identified in those reports are still evident today. However, there is now a great deal of cooperation between mathematics societies and the National Academy of Sciences, the National Science Foundation, and many private foundations to find ways to revitalize mathematics education. For example, the MAA recently received a one-year planning grant from the National Science Foundation for a "Curriculum Action Project" which seeks, among other things, to identify issues of special importance in undergraduate mathematics, to explore new mechanisms for curricular reform, and to broaden horizons of mathematical applications.

Still, mathematics educators nationwide struggle with the problems of underprepared students and the ever increasing numbers of developmental mathematics courses being taught in the colleges and universities. In Tennessee, for instance, approximately 70% all entering first year students must take remedial and/or developmental mathematics courses. Also the number of required remedial and/or developmental courses for underprepared students in Tennessee range from a low of one to as many as four at some colleges. In 1983, George expressed concern about the preparation of mathematics and science students in higher education:

> Whether measured by changes in standardized test scores over the last few years, by personal observation in the classroom, or by the growth of "special" mathematics and science courses, the conclusion is almost inescapable: generally speaking, students entering our colleges and

> universities do not understand science, have lessened facility with mathematical manipulation, and do not have adequate comprehension of mathematical concepts. (p. 207)

He suggested that part of the problem for this lack of preparation might be curricular design and quoted from Today's Problems, Tomorrow's Crises by the National Science Board's Commission on Precollege Education in Mathematics, Science, and Technology:

> There is evidence that many students who have an interest in mathematics, science, and technology are not being reached through instructional approaches currently used in the classroom. Whereas many students do not like school science - and form this opinion by the end of the third grade - many do like the science and technology that they see on television. They also like what they encounter at science and technology museums, planetariums, nature centers, and national parks. (p. 208)

There is wide-spread agreement that there are problems in mathematics and science education at all levels. In 1991, the Mathematical Sciences Education Board (MSEB) published Counting on You, a distillation of the basic issues described in three reports of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine: Everybody Counts, Reshaping School Mathematics, and Moving Beyond Myths. It also summarized the recommendations found in Curriculum and Evaluation Standards for School Mathematics, Professional Standards for Teaching Mathematics, and A Call for Change: Recommendations for the Mathematical Preparation of Teachers of Mathematics. In Counting on You the MSEB stated:

> Teachers of mathematics are leading a nationwide effort to bring about a complete redesign of school and college-university mathematics programs. By means of an unprecedented series of publications, they have set new and more demanding standards for what our students must learn about mathematics and for what the teachers themselves must accomplish as professionals in the classroom. (p. 1)

In commenting on the fourth of six national education goals set by the President of the United States in 1990, that U.S. students should be first in the world in mathematics and science achievement by the year 2000, the MSEB (1991) listed the harsh realities we face today:

> * When compared with students of other nations, U.S. students lag far behind in mathematical and scientific accomplishment.
>
> * Too many students, including a disproportionate number from minority groups, leave school without having acquired the mathematical and scientific literacy necessary for the workplace or for productive lives.
>
> * Public attitudes, which are reflected and magnified by the media, encourage low expectations in math and science. Only in these subjects is poor school performance socially acceptable.
>
> * Curricula and instruction in our schools and colleges are years behind the times; they do not reflect the increased demand for higher-order thinking skills, the greatly expanded uses of mathematics and science, or what we now know about the best way for students to learn these subjects.
>
> * Calculators and computers have had very little impact on mathematics and science instruction, in spite of their great potential to enrich, enlighten, and expand students' learning.

* Commonly employed methods of evaluation - especially standardized, paper-and-pencil, multiple-choice tests of "basic skills" - are themselves obstacles to the teaching of problem-solving and higher-order thinking skills, as well as the use of calculators and computers. (p. 4)

Obviously the MSEB found the goal of the President difficult if not impossible to reach. The 1991 report summarized its conclusions thus:

> For U.S. students to excel in mathematics and science achievement by the next decade, much more will be required than merely trying harder or tightening outmoded accountability measures. A fundamental restructuring must take place nationwide - changing what is taught, the way it is taught, and how we evaluate the results - and it is needed as rapidly as possible. (p. 4)

The MSEB (1991) spoke for all national mathematics organizations in Counting on You when it stressed the need for goals for student performance to shift from a narrow focus on routine skills to development of broad-based problem solving skills. Goals for student performance stressed by MSEB included the following: (a) students should be able to estimate answers to problems mentally, and if precise answers were needed, use calculators to find them; (b) students should be familiar with tables, graphs, spreadsheets, and statistical techniques to present material and to understand material presented by the media and others; (c) students should be able to select appropriate problem solving strategies for a given situation.

Also, the MSEB (1991) stated that goals for teacher performance were shifting from a focus on authoritarian models based on "transmission of knowledge" and "drill and practice" to student-centered methods featuring "stimulation of learning" and "active exploration" (p. 7). These changes were suggested to encourage motivation and to positively affect student learning. As described by the MSEB, goals for teacher performance included: (a) teachers should behave more like intellectual coaches by encouraging students and building confidence that they can learn mathematics; (b) teachers should help students verbalize mathematical ideas and realize that there was more than one way to reach solutions to problems. However, again, there was little empirical evidence to support such conclusions.

The Curriculum and Evaluation Standards for School Mathematics (Standards) established by the NCTM (1989), in an effort to improve mathematics teaching, called for five new goals for students: "(1) that they learn to value mathematics, (2) that they become confident in their ability to do mathematics, (3) that they become mathematical problem solvers, (4) that they learn to communicate mathematically, and (5) that they learn to reason mathematically" (p. 5). In addition to these goals, the NCTM argued that calculators should be available to all students at all times and stressed that student activities should grow out of problem situations. It criticized current teaching methods:

> Traditional teaching emphases on practice in manipulating expressions and practicing algorithms as a precursor to solving problems ignore the fact that knowledge often emerges from the problems.

> This suggests that instead of the expectation that skill in computation should precede word problems, experience with problems helps develop the ability to compute. Thus, present teaching strategies for teaching may need to be reversed; knowledge should emerge from experience with problems. In this way, students may recognize the need to apply a particular concept or procedure and have a strong conceptual basis for reconstructing their knowledge at a later time. (pp. 10-11)

The American Association of Physics Teachers, the American Chemical Society, the National Association of Biology Teachers, and the National Society of Professional Engineers are among the many groups who have added their support for the mathematics curricula described by the NCTM Standards. These Standards specify four major curricular emphases: problem solving, communication, reasoning, and mathematical connections (transfer of learning). With such broad-based support, the NCTM Standards can be viewed as national guidelines for what young people ought to know about mathematics.

Further, Linda Sons, chair of a new Subcommittee on Quantitative Literacy established by the Committee on the Undergraduate Program in Mathematics (CUPM), decried the cookbook type approaches used to teach word problems in algebra. She noted that many reports bemoaning the lack of quantitative literacy have been issued recently in which masses of statistics, charts, and graphs, and conclusions drawn from these statistics, charts, and graphs were presented. She asked the question, "But how many educated people can understand them or question their validity?" (Sons, 1990)

Besides the emphasis on the NCTM Standards, other recent reports also stress the need for innovation in science and mathematics education. In an article comparing three of these reports, Kullman (1989) stated:

> Although Everybody Counts, Science for All Americans, and the NCTM Standards were developed independently of each other, there is a remarkable degree of harmony in their recommendations. All seem to agree that there is a need to reduce the emphasis on rote memorization, to involve students more actively in the learning process, to relate mathematics to other branches of knowledge, and to make better use of calculators and computers....
>
> While the reports cited in this article are capturing national attention, they should not be taken as a sign that solutions to the problems of mathematics education have been found. In fact, the writers of the reports make it clear that their recommendations are only a beginning. (pp. 15-16)

These reports document the need for educational strategies which resolve deficits in our mathematics education - lack of applicability, lack of transfer, and lack of problem solving skills. A short report from the Educational Testing Service (1989b) contended:

> A common thread through all educational assessments is the distinction between the mastery of basic knowledge (where American students have generally improved) and the ability to think, analyze, and synthesize (where American performance is low and generally stagnant)....
>
> In mathematics the U.S. is last in the ability to engage in routine manipulation of numbers and in the ability to carry out standard procedures that lead directly to answers. It is virtually at the bottom in "problem-solving" requiring higher-order thinking skills to screen relevant from irrelevant information, determine

> what information is needed to solve a problem, and formulate generalizations. (p. 6)

The situation was poignantly addressed by Carl Sagan, a prominent astronomer, who stated that "we live in a society - and a nation, and a world - exquisitely dependent on science and technology, in which hardly anyone knows anything about science and technology" (Educational Testing Service, 1989b).

Some blame the problems on curriculum emphasis on rote memorization and drill. Fandreyer (1991) described the template method as being the prevalent teaching method in the United States: "The teacher demonstrates the solution to a problem, thereafter the students apply the demonstrated pattern to solve any number of similar problems, with more of the same for homework" (p. 6). Students become so inured to following established patterns that they are unwilling to try to construct a solution on their own. Many can only solve problems exactly like the ones to which they have already been exposed. The MAA (1990b) argued that the traditional teaching format produced passive learners by emphasizing "bite-sized problems to be solved by techniques provided in the textbook section in which the problem appears" (p. 8). Further, the MAA contended:

> At its best, mathematics overflows with connections, both internal and external.... At their worst, especially in lower - division courses through which both majors and non-majors must pass, they (teachers) reveal mathematics as a bag of isolated tricks: problems in elementary courses are often solved more by recognition of

> which section of the text they came from than by any real understanding of fundamental principles. (p. 14)

In a similar statement, Waits (1990) stressed that

> for too many concepts, the current curriculum scratches the surface and fails to dig deeply enough for students to acquire needed understanding. The curriculum should stress problem solving. (p. 32)

Many blame the problems of mathematics education on the lack of integration with other fields and the limited emphasis on applications and on problem-solving skills. The MAA (1990b) stated this problem clearly:

> Mathematicians also frequently know almost nothing about the expectations held by their colleagues in cognate disciplines for the mathematics preparation of students with other majors. It is not uncommon for the three interested parties - mathematics professors, science faculty advisors, and students - never to discuss goals or objectives, but only credit hour requirements. It should come as no surprise that in the absence of good communication, misunderstandings flourish. (p. 20)

A National Science Foundation (1991) report stated that undergraduate science, mathematics, and engineering education needs innovation. In addition, the report spoke to the need for interchange between and among disciplines:

> The historical traditions of disciplinary activity in universities are a major barrier to formation of an interdisciplinary community of science, mathematics, and engineering educators. Normally, there is little interchange between and among fields about teaching methods that could cut naturally across discipline lines. (p. 3)

A joint report, "Curriculum for Grades 11-13," approved in 1987 by the Board of Directors of the NCTM and by the Board of Governors of the MAA, urged greater integration of topics in the curriculum for students in grades 11-13:

> It should be pointed out that there is yet another aspect of integration that needs further study. This is the possibility of integrating mathematics with other disciplines, particularly science. (p. 94)

Kaput (1985) stated that "students at all age levels have little ability to relate their school mathematics to the wider world of experience" (p. 312), while Curnutt (1985) made even more specific observations:

> There are reasons to believe that secondary school mathematics and the remedial college curriculum are stuck in a rut and each is digging the hole a little deeper for the other (these reasons include the exclusive pre-calculus orientation of remedial courses; lack of ... applications; emphasis on routine but unmotivated, algebraic techniques, justified by "you will need this for subsequent college math courses"). (p. 33)

Perhaps, however, the MAA (1990b) best summarized the most perplexing problem facing the mathematical community:

> Mathematics shares with many disciplines a fundamental dichotomy of instructional purpose: mathematics as an object of study, and mathematics as a tool for application.... Typically faculty interests favor the former, whereas student interests are usually inclined towards the latter. (p. 2)

This dichotomy may well be the basis for the lack of applications in mathematics courses today.

Transfer of Learning

Mathematics instruction presently does not make clear the application of mathematics to real life (in favor of the mathematics as a discipline mindset). It is equally true that students do not see that mathematics learned in the classroom is needed in the study of other fields; in other words, students do not transfer mathematical skills to other related courses.

> Transfer is the psychological term for the ability to utilize concepts from one area, for example, mathematics, in dealing with a second area, such as chemistry. It is the ability to combine basic concepts or principles, and then apply them to a variety of problems. (Menis, 1987, p. 105)

Several authors (Bender, 1986; Mandinach, 1987; Milton, 1971; Perkins and Salomon, 1988; Royer, 1979; Voss, 1978; Yates and Moursand, 1988-89) have looked at transfer in a generic way. Bender (1986) claimed that the implicit goal of any educational endeavor was to provide the learner with knowledge or skills which may be transferred to other situations. Royer (1979) defined transfer as the extent to which learning in one situation contributes to or detracts from subsequent instructional events.

Frequently, learning has been defined as evidence that information has been transferred. Voss (1978) outlined a cognitive theory of learning in which learning was defined as transfer. That which is transferred is not just factual knowledge, but procedural and contextual information as well as the relational structure of information. Bender (1986) contended that "the more the individual learner monitors the ongoing problem solving, the greater the transfer should be to subsequent problem-solving tasks. Thus, an instructional event which facilitates the learner's monitoring should also facilitate transfer" (p. 162). Voss (1978) also noted that among other requirements for developing a theory of learning and for achieving transfer, a better understanding of the instructional techniques which affect transfer was needed.

Perkins and Salomon (1988) stated that transfer occurred when the "knowledge or skill associated with one context reached out to enhance another" (p. 22). However,

> The implicit assumption in educational practice has been that transfer takes care of itself. To be lighthearted about a heavy problem one might call this the Bo Peep theory of transfer. Let them alone and they'll come home, wagging their tails behind them.... If they learn some problem solving skills in math ..., this will more or less spill over to the many other contexts in and out of school where it might apply, we hope. (p. 23)

Perkins and Salomon (1988) listed an array of research which implied that the Bo Peep theory did not work. In answer to the question of why transfer should prove so hard to achieve, they stated:

> Several explanations are possible. Perhaps the skill or knowledge is not well learned in the first place. Perhaps the skill or knowledge in itself *is* adequately assimilated but *when* to use it is not treated at all in the instruction....
>
> While these explanations have a commonsense character, one other contributed by contemporary cognitive psychology is more surprising: there may not be as much to transfer as we think.... The problem-solving abilities they (students) develop in math and

> physics may be much more specific to those contexts than one would imagine. Skill and knowledge are perhaps more specialized than they look. This is sometimes called the problem of "local knowledge." (p. 24)

Perkins and Salomon (1988) described two very different mechanisms of transfer: low road transfer and high road transfer. The way learning to drive a car prepares a person to drive a truck is an example of low road transfer. The authors defined low road transfer as "automatic triggering of well-practiced routines in circumstances where there is considerable conceptual similarity to the original learning context.... High road transfer depends on deliberate mindful abstraction of skill or knowledge from one context for application in another" (p. 25). The authors described two types of high road transfer: forward reaching and backward reaching.

> In forward reaching high road transfer, one learns something and abstracts it in preparation for applications elsewhere.... In backward-reaching high road transfer, one finds oneself in a problem situation, abstracts key characteristics from the situation, and reaches backward into one's experience for matches.... High road transfer always involves reflective thought in abstracting from one context and seeking connections with others. This contrasts with the reflexive automatic character of low road transfer. (p. 26)

The authors found that more successful transfer occurred in low road transfer situations:

> When the conditions for low road transfer are met by chance, as in many applications of reading, writing, and arithmetic, transfer occurs - the sheep come home by themselves. Otherwise the sheep get lost. (p. 28)

The authors suggested that we could teach for transfer by designing instruction to meet the conditions of transfer. Two techniques which they suggested to promote transfer were "hugging" and "bridging." "Hugging" means teaching for low road transfer; "bridging" means teaching to better meet the conditions for high road transfer. Rather than expecting students to achieve transfer spontaneously, the teacher should look for ways to help students learn to abstract and make connections. Teaching for transfer is not just teaching particular knowledge and skills for transfer but teaching students in general how to learn to facilitate transfer.

Yates and Moursand (1988-89) commented that

> We improve as problem solvers with experience, but we seem to have difficulty transferring that knowledge to analogous problems in other domains.... All teachers should teach for transfer....
>
> The more you know about a particular area or the more knowledge you have about a subject, the better problem solver you tend to be on problems within that subject....
>
> No general problem solving heuristic applies equally to all disciplines. The basic modes of inquiry, thought, and problem solving vary greatly across domains. We know that students will get better at this transfer if they receive specific instruction and practice in it....
>
> A prodigious memory may not enhance problem solving skills; but rather, a set of carefully refined problem solving strategies can be a more significant influence on performance in a given domain of discourse. (p. 12+)

Mandinach (1987), in a study about transfer and computers, concluded that

> Instruction that accompanies many computer-based activities fails to make explicit the connections among tasks and how the targeted skills can be applied in other domains. One cannot expect transfer to occur spontaneously for most learners. Instead, students need assistance in making the connections and need to observe appropriate applications of the targeted skills. (p. 4)

Among the authors (Bassok and Holyoak, 1989; Bunce and Heikkinen, 1986; Crocker, 1991; Menis, 1987; Putnam, 1987; Schoenfeld, 1983, 1985; Segal and Chipman, 1984) who have addressed the issue of transfer in mathematics and science, several have specifically discussed the lack of transfer from mathematics to chemistry and physics.

Putnam (1987) noted that helping students learn mathematics in ways that enable them to transfer their knowledge has been an enduring problem in mathematics education. He stated that

> many mathematics educators and researchers have argued that more transfer ... would occur if instruction were made *meaningful* rather than *rote*.... While there is widespread agreement that mathematics instruction should somehow go beyond rote drill and practice ..., there is much less agreement on what kind of instruction *should* be taking place and, indeed, just what constitutes the mathematical understanding thought to be so important for transfer to occur. (p. 688)

He suggested that students should be exposed to a variety of ways for learning mathematical concepts. He emphasized the importance of linking mathematics with other knowledge structures and argued that mathematics could not be learned well as isolated bits of information. "Links among bits of knowledge and among various domains are a critical aspect of the mathematical understanding needed for transferring knowledge appropriately" (p. 692).

Putnam further argued that

> two aspects of transfer are of central concern in mathematics education: application of mathematics skills and concepts to solving problems in various settings; and providing a foundation for learning additional concepts, both in higher levels of mathematics and in other domains, such as science. (p. 701)

Finally, Putnam stressed that although learning content was certainly important, students should also be encouraged to talk about mathematical procedures, not just to do mathematical procedures. He argued that verbalization of mathematical procedures led to understanding of concepts and might increase transfer. In a similar vein, Schoenfeld (1983) argued that heuristics would not transfer if only practice was provided. Students must also be specifically instructed in what they are doing and why it was useful. Shoenfeld was critical of rote memorization, two-minute exercises to the exclusion of real problems, step-by-step procedure, and preparation for standardized tests.

According to Crocker (1991), for students to acquire the ability to solve problems, they must first acquire the ability to transfer knowledge and skills to new areas. Bassok and Holyoak (1989) posited that the major requirement for ensuring successful transfer was fostering student access to relevant prior knowledge. Glaser (1984) noted that individuals could be taught knowledge of a rule, a theory, or a procedure, but if transfer of learning to new situations was a criterion, then they needed to know how to use this knowledge.

The MAA (1990a) stressed the need for connecting mathematical ideas by developing an understanding of the interrelationships within mathematics, by exploring the connections that exist between mathematics and other disciplines, and by applying mathematics learned in one context to the solution of problems in other contexts. This is the essence of the transfer issue: in addition to learning mathematical skills, students should gain the ability to connect mathematics with other disciplines and contexts.

Proposed Solutions

Comments made by mathematics educators lend credibility to the existence of problems and the need for solutions in mathematics education. Further, these educators call for action, especially in the initiation of new strategies to resolve these problems. In an invited address at the 75th anniversary celebration of the Mathematical Association of America in Columbus, Ohio, on August 8, 1990, Peter Hilton (1990) said,

> I am utterly opposed to "cookbook" courses for any students, because they are tedious (to give as well as to receive) and ineffective.... As teachers we must realize that, if we teach for understanding and give our students opportunities for practice, the necessary skill will result; but if we teach merely for skill, no understanding will result, no flexibility will be acquired, and the skill itself will not survive. (p. 4)

Commenting on proposed curricular changes, Hadley (1990) stated:

> For decades, curricular initiatives have come and gone with little or no effect on mathematics education. The mathematics classroom today is almost identical to the classroom of thirty years ago. To change this scenario, NCTM's curriculum standards must be implemented as quickly as possible, and classroom teachers must be the agents of change. (p. 512)

Monthly publications from organizations such as the NCTM, the MAA, the American Mathematics Association of Two Year Colleges, and the American Mathematical Society continue to search for ways to improve mathematics education.

Many suggest that applications which encourage transfer to other disciplines must be an integral part of every mathematics course. Efforts to motivate and interest students are exemplified by mathematics departments which emphasize excellent introductory instruction using realistic applications as discussed by Albers, Rodi, and Watkins (1985). Akst (1985) reflected that

> The curriculum must be appropriate.... As to the calculator question, it is critical that arithmetic courses continue to cover conventional algorithms, but that they also teach the use of the calculator (estimation, constants, memory, scientific notation, etc.).... Instruction and testing should emphasize

> applications and word problems, with many examples taken from followup courses, so as to promote carry over. (pp. 150-151)

Steen (1989) stated that topics included in remedial courses should be illustrated with concrete applications to make these courses "fresh, interesting, and significant" (p. 105).

Curnutt (1985) agreed with the NCTM report, An Agenda for Action: Recommendations for School Mathematics of the 1980s, in giving problem-solving top priority:

> Implicit in a problem-solving emphasis is that problem-solving should involve relevant applied mathematics ... and that the mathematical concepts and techniques should be well motivated and meaningful to the student.... Skills should not be taught in isolation from their uses. Instead, some applications should come first. The usefulness of symbolic manipulation must be made clear. (p. 35)

Washington (1985) continued with this line of reasoning by stating that

> helping to motivate students enrolled in technical and vocational programs is one of the major reasons for the emphasis on applications. When the mathematics is related to their curriculum through the use of appropriate allied problems (rather than the approach where applications are used infrequently), students better understand the need for the mathematics that they are expected to learn. ... The CUPM Panel in 1982, in giving their recommendations for college graduates, stated that courses "should be designed to be appealing and significant to the student," and that "almost all undergraduate courses in mathematics should give attention to applications." (p. 123)

Though applications to real problems are often suggested as a way to improve mathematics achievement, others propose integrating calculators and/or computers into the instructional process. Johnson (1989) believed that calculators would have a positive influence on mathematics instruction and learning and stated that

> our goal must be a reconceptualization of mathematics instruction. This reconceptualization must include the integration of technology into instruction, but in a way which encourages conceptual understanding and not rote memorization of procedures in a mindless search for the "answer." ... What is needed in many cases is a strategy for rebuilding students' mathematical knowledge from the ground up, rather than merely to repair some isolated deficiencies.... We must open new representational windows for our students so they can form conceptual images which foster understanding rather than rote memory. (p. 5)

The January 1991 NCTM News Bulletin had a front page story entitled "Major Calculator Project is Launched." NCTM and MAA are jointly sponsoring series of workshops to provide teachers with the information and skills which they will need to use calculators effectively in the middle and high schools. The 1990-91 NCTM Position Statements urged the integration of calculators into the mathematics program at all grade levels.

The NCTM (1991a) recommended integrating calculators into school mathematics programs at all grade levels in classwork, homework, and evaluation. Further recommendations admonished publishers and authors to integrate the use of calculators into their materials. Similarly, the MAA (1990a) stressed the use of technology: "use calculators ... to pose problems, explore patterns, test conjectures, conduct simulations, and organize and represent data" (p. 7).

The consensus that applications, transferability, and technology, particularly in the form of calculators, can make a difference in mathematics education is stressed in the 1983 College Board publication describing Project EQuality. In addition to stressing the need for calculator usage, two other goals pertinent to this study were given: (1) the ability to apply mathematical techniques in the solution of real-life problems and to recognize when to apply those techniques (p. 20) and (2) the ability to select and apply mathematical relationships to scientific problems (p. 23).

Komas (1990) added that the learning of mathematics should be an interactive experience:

> The concept of mathematics as a laboratory science, while not necessarily new, has received considerable attention as of late. The idea that mathematics is a world to be explored rather than a known quantity is central to this theme. Using computers and calculators, students can explore mathematics, hypothesize, test their hypotheses, and draw conclusions. Students can discover mathematics rather than have it told to them. Thus the study of mathematics becomes an interactive experience rather than a passive observation. (p. 4)

An example of this approach in practice was provided by DeLorenzo (1989), who characterized himself as a scientist, a practitioner of mathematics rather than a research mathematician. In other words, DeLorenzo used mathematics as a tool to explore his scientific interests rather than a separate research discipline. His goals for the educational process included the following: to teach students to communicate clearly, to study regularly, to master basic math skills, and to think logically. He tried to develop basic mathematics skills in part by developing estimation skills along with calculator proficiency. He stressed that mathematics students, like scientists, needed to verify their solutions by arriving at answers through these two mutually independent approaches. He asked pre-solution questions that required students to determine if a problem could be worked with the given information. This made students think about the process of solution. He also asked post-solution questions such as: What does this answer mean? Does this answer make sense? A similar approach was described by Waits (1990). Dion (1990), Holden (1989), and Leitzel (1985) also described the use of calculators in mathematics classrooms.

Steen and others considered both approaches, that of including applications and that of utilizing computers and calculators in the classroom, as viable strategies for improving instruction. Steen (1987) summed up both those ideas well:

> *School mathematics should use computers and calculators.* Computers now compute, so students should learn to think. More important, students need to learn at every grade level when to use their heads and when to use their machines.
> *Mathematics in the schools should be linked to science in the schools.* To achieve this goal science teachers must actually use mathematics, mathematics

> teachers must use science, and mathematics and science teachers must discuss coordination of their teaching. (p. 237)

Although ideas and suggestions abound in the literature about the improvement of mathematics instruction and how such improvement might relate to science instruction, there is little empirical research to support or disprove these ideas. There is an appalling lack of empirical research to guide the development of instruction and to verify the existence of transfer from one subject to another.

Throughout the literature, several common suggestions for resolving the difficulties in mathematics education appear, sometimes together, and sometimes in isolation. They may be summarized as follows:

(1) Students need to be instructed in problem solving rather than rote learning.

(2) Applications from other disciplines and from the working world are possible ways to encourage transfer of knowledge and problem solving skills.

(3) Use of hand held calculators in the classroom may provoke interest and may increase problem solving ability and understanding.

However, little empirical research has been conducted to validate or disprove the first two theories, although research has begun on the third, sparked by Demana and Waits at Ohio State.

Summary

The state of mathematics education in the United States has become a matter of grave concern for educators and the public alike. American students' scores on standardized mathematics tests continue to decline, and many professional educators state that declining mathematics achievement is affecting students' performance in the sciences as well. Although much speculation concerning transfer of learning exists, there is little empirical research which demonstrates how such transfer occurs, particularly in mathematics and the sciences. Several educators have posited that the greater use of applications in instruction would increase transfer from mathematics to the sciences. Others have suggested that the use of calculators would relieve students of drudgery and encourage transfer. A combination of these two approaches - that is, increased applications in instruction and the use of calculators - may encourage transfer of learning. While the literature suggests that combining the two approaches will encourage transfer, there is no empirical evidence that transfer will indeed result from use of such strategies. This study attempts to fill that void.

CHAPTER III

METHODS AND PROCEDURES

To determine what effect, if any, a basic mathematics/ elementary algebra course designed to integrate mathematics and science and to use the calculator extensively would have on mathematics achievement, on chemistry achievement, and on the transfer of mathematical skills to a subsequent chemistry course, an experimental study was conducted at Chattanooga State Technical Community College (CSTCC) during the 1991-92 academic year. This chapter describes the setting for the study, the subjects involved, the design of the study, the procedures used, and the data collection and analysis.

Setting

CSTCC is an urban, two year college of approximately 10,000 students in Chattanooga, Tennessee. It is governed by the Tennessee Board of Regents (TBR). The college practices an open-door admissions policy, which means that any student with a high school diploma or with a GED credential may be accepted into its programs. CSTCC attracts students who are denied admission to other colleges because of lack of preparation. Approximately 70% of entering students are underprepared and must take remedial and/or developmental mathematics courses.

The college has a number of associate degree level programs in allied health areas which have specific admission requirements. One such requirement for admission to allied health programs is chemistry. Since chemistry has a mathematics prerequisite, remedial and developmental students seeking admission to allied health areas enroll first in mathematics so that they can take chemistry the following semester.

Developmental Studies, a series of courses prescribed by the State of Tennessee to prepare underprepared students to do college level work, provides courses in remedial and developmental English, reading, mathematics, and study skills. This core of courses comprises the second largest division within the college, approximately 4000 students. The mathematics sequence provides remedial Basic Mathematics/Elementary Algebra (MA070) and developmental Intermediate Algebra (MA081). Students completing this sequence successfully are prepared to enroll in College Algebra (MA117) and/or other algebra-based courses such as Principles of Chemistry (CH104), Concepts of Physics (PH110), and Statistics (MA153).

Subjects

The population for this study consisted of students who were enrolled at CSTCC during the 1991-92 academic year and who met the following criteria:

(1) They planned to major in nursing or another allied health field.

(2) They completed MA070 as part of the remedial mathematics requirements during the 1991 Fall semester.

(3) They completed CH104, a basic chemistry course reminiscent of high school chemistry, during the 1992 Spring semester.

Mathematics placement is determined by the Academic Assessment Placement Program (AAPP) test, which is taken by all students in the TBR system who score less than 19 on the enhanced ACT test or who are over 21 years of age. Students placed in MA070 have not achieved control of arithmetic skills (working with whole numbers, fractions, proportions, decimals, and percents) and traditional high school first year algebra skills (working with integers and rational numbers, solving equations, making conversions, manipulating formulas, working with polynomials, performing operations with exponents, understanding scientific notation).

Design

An experimental/control group design was selected to test the hypotheses guiding the study (see pages 9-11). The researcher taught two classes of MA070, the basic remedial mathematics course, during Fall 1991; one was randomly selected as the experimental group, the other as the control group. Students from both groups who successfully completed MA070 and who subsequently enrolled in CH104 in Spring 1992 were tracked throughout that semester. Data were collected and analyzed on those students who completed CH104.

Procedures

The researcher took CH104 at CSTCC during Summer 1990 in order to familiarize herself with the mathematical problems which students encountered in chemistry. As a result of this experience, study of the literature, and consultation with the chemistry department at CSTCC, four mathematical topics essential for success in basic chemistry were determined: solving proportion and percentage problems, manipulating formulas, making conversions, and understanding scientific notation and significant digits.

Using these topics, an experimental curriculum for the basic mathematics/elementary algebra course was designed integrating these mathematical procedures with applicable topics from chemistry, anatomy and physiology, nutrition, and pharmacology. Also, since calculators were encouraged and expected in the science classes, this curriculum, unlike the standard algebra curriculum, was designed to make full use of calculators, allowing the student to focus on the topics instead of the arithmetic mechanics of doing them. The reason for using the calculator is best stated by Demana and Leitzel (1989): "The calculator allows problems to be more realistic and complex. Many significant problems are not readily accessible with paper and pencil techniques" (p. 3).

A pilot study using the experimental curriculum design which emphasized applications and the use of calculators was conducted at CSTCC during the 1990 fall semester in a basic mathematics/elementary algebra course taught by the researcher. In the pilot study, the researcher incorporated the calculator into every aspect of the course. Adjustments, alterations, and improvements to the curriculum design were made as a result of the pilot study.

After the experimental curriculum was designed and refined, two MA070 classes in Fall 1991 were designated as special sections for students interested in pursuing allied health majors. During summer orientation, the researcher informed new students requiring MA070 about the special sections for students interested in allied health fields (see Appendix A). Students who registered in each of the special MA070 sections agreed to take CH104 in the spring semester. The sections were not designated as control or experimental until after registration in order to randomly designate the control or experimental group. The control group contained 23 students; the experimental group contained 25 students.

The first day of class students in both groups were told that they were part of an experimental study to increase their chances of success in CH104. Both groups were told that although all of the material in the departmental syllabus for MA070 would be covered, topics which they would use in CH104 would be identified and stressed. In addition, students in the experimental group were told that they could use calculators throughout the course. Those who did not wish to participate in the study were given the opportunity for reassignment to another section not part of the study. None asked to be moved. All students signed consent forms agreeing to participate and giving permission for their work and observations to be used in the study (see Appendix B).

To determine if the entering skills and aptitudes were the same for both the control and the experimental groups, mean entrance AAPP test scores were compared. Calculators were not allowed on the test. In order not to prejudice the study, the statistical comparison between the two groups was not made until the study was completed.

During Fall 1991 both designated sections of MA070 were taught by the researcher using a popular basic text (Keedy and Bittinger, 1988). Broad topics covered in each section included whole numbers, fractional and decimal notation, proportions, percents, integers and rational numbers, solving equations, polynomials and factoring, manipulating formulas, performing operations with exponents, making conversions, and understanding scientific notation.

Control Group. The control group, consisting of 23 students, was taught a standard basic mathematics/elementary algebra course stressing mathematical procedures rather than applications, without using calculators as an integral part of the class. The control group was taught using the traditional textbook (Keedy/Bittinger, 1988) as the basis of the curriculum. The textbook emphasizes rules, formulas, and computational skills. This textbook, with minor revisions, has remained virtually unchanged for at least 15 years. The researcher taught the material as it appears in the textbook with no extra applications.

The Keedy/Bittinger approach, as is true of traditional mathematics instruction, involves the presentation of algorithms and rules to be memorized prior to working with applications. In other words, in concert with traditional instruction, the textbook approach moves from the abstract to the concrete. Although the authors state in the preface (p. v) that this edition contains more applications, most chapters contain long sections of paper and pencil drills followed by one applications section near the end of the chapter. The final examination provided by the authors contains 118 questions, including 106 procedural problems and 12 application problems, illustrating the lack of emphasis placed on applications by these authors.

Using their approach to percents, for example, students are taught to solve simple problems involving percents using a set of rules or algorithms. The objectives as stated in the first three sections of the chapter are:

* Write three kinds of notation for a percent.
* Convert from percent notation to decimal notation.
* Convert from decimal notation to percent notation.
* Convert from fractional notation to percent notation.
* Convert from percent notation to fractional notation.
* Memorize the table of decimal, fractional, and percent equivalents, and be able to state them.
* Translate percent problems to equations.
* Solve percent problems: (16 is what percent of 40?)

Students are shown examples illustrating each objective and are then assigned drill problems identical in nature to the examples for homework. The applications begin in section four, and almost all are business oriented. The students are expected to work the problems using a standard algorithm which recognizes the verb as the equal sign and the word "of" as multiplication.

Experimental Group. The experimental group, consisting of 25 students, was taught basic mathematics/elementary algebra integrating mathematics and science, using the calculator as an integral part of the class. The experimental group was taught using the same textbook as the control group to eliminate the variability introduced by using a completely different textbook. However, in contrast to the instruction provided the control group, the textbook was used primarily as a reference and as a source of homework problems, not as the primary vehicle for introducing new topics. Students received supplementary material containing applications suggested by instructors in chemistry, anatomy and physiology, nutrition, and pharmacology. This material was used to introduce new topics with concrete applications so that students could see specific uses of the topics. After class discussion established a desire for a method of solving such application problems, algorithms and rules from the textbook were introduced. Thus, instruction for the experimental group moved from the concrete to the abstract, the reverse process from the traditionally taught class. In addition, the calculator was used continually from the beginning of the course.

Using the topic of percents as an example of the experimental approach, students were asked to bring in nutrition labels from packaged food before beginning the study of the topic. Fat grams, cholesterol, and sodium were discussed to see what understanding the students had of percentages of fat and amounts of fat, cholesterol, and sodium in their diets. The class looked at the labels that were brought in and discussed some of the conclusions on the labels. Questions asked were as follows: What does it mean to claim that this product supplies 300% of the U. S. recommended daily allowance (U.S. RDA) of vitamin A? What does it mean when two products claim to have 9 fat grams, but the percentages of fat are very different? Another topic which was discussed before looking at the mechanics of percents was the amount or percentage of a certain chemical in the air caused by human pollution (such as acid rain and carbon monoxide) or natural pollution (such as pollen). After exploring the concrete applications, the textbook rules and algorithms for the mechanics of working with percents were presented. Finally, applied percent problems were solved using applications from chemistry and biology as well as the business applications in the textbook.

Although these classes were taught using two different methods and perspectives, they covered the same mathematical material. At the same point in the semester, students took the same tests provided by the authors of the textbook. The students in the experimental group were allowed to use calculators to take the tests; those in the control group were not. Although the students in the experimental group were not tested on the instructor-added applications, they were exposed to a variety of applications used to motivate learning of mathematical topics. The control group was not exposed to these applications. After completion of MA070, the students in the experimental group had a semester's experience working with the calculator in their mathematics class, an experience the students in the control group did not have. Calculator usage was required by all students in the chemistry classes.

The researcher helped each of the students who completed MA070 register for CH104 in the 1992 spring semester. Not all eligible students in the designated sections of MA070 subsequently enrolled in CH104. Of the 18 students who completed the control MA070, 11 enrolled in CH104; of the 14 students who completed the experimental MA070, 9 enrolled in CH104. All 20 students who completed MA070 and who took CH104 were enrolled in one of two CH104 sections taught by the same chemistry teacher in order to eliminate instructor variability in CH104.

As well as studying the achievement of the groups in mathematics and chemistry, the researcher was interested in students' perceptions toward mathematics. The researcher identified instruments designed to measure anxiety and attitude developed by C. Ann Oxrieder and Janet P. Ray as a portion of their text, Your Number's Up: A Calculated Approach to Successful Math Study (1982). These instruments were given to both groups at the beginning of the semester to determine if there were significant differences in attitude toward mathematics and anxiety level about mathematics. The same instruments were given as post-tests at the end of the semester to determine if curricular and instructional design had affected the level of mathematics anxiety and attitudes toward mathematics.

Data Collection and Analysis

Four types of data were collected: measures of achievement in mathematics, measures of achievement in chemistry, measures of transfer from mathematics to chemistry, and surveys about student attitudes and anxiety levels toward mathematics. These data were analyzed to see if there were any statistical differences in achievement in mathematics, in achievement in chemistry, in transfer from mathematics to chemistry, and in attitudes and anxiety levels between the control and the experimental groups.

Achievement. Achievement in mathematics and chemistry was calculated for each student for each of the courses based on student final examination results and final grade averages. Mean test scores for both the control and experimental groups were gathered from the final examination provided with the Keedy/Bittinger textbook, the departmental mathematics diagnostic test given in the chemistry course to ascertain readiness for chemistry, and a teacher-made chemistry final examination. The same tests were given to each group. Mean final grade averages in both mathematics and chemistry were computed. Students in the experimental group used calculators on all mathematics tests; those in the control group did not use calculators on any tests given in the mathematics class. Students in both groups used calculators on the mathematics diagnostic test given in chemistry and on all chemistry tests.

For each set of data, each mean score in the experimental group was compared to the corresponding mean score in the control group. In order to determine whether the results were statistically significant at the 0.05 level, an analysis was made using the Student's t distribution.

Transfer of Learning from Mathematics to Chemistry. The researcher assumed that transfer of learning was achieved if a student demonstrated mastery of a specific type of problem on chapter tests or the final examination in mathematics and subsequently on the final examination in chemistry. The researcher designated problems of the following types: four problems on solving proportions and percentages, four problems on formula manipulation, and four problems on making conversions in each course. Three problems were identified in mathematics and four in chemistry to determine transfer of understanding of scientific notation and the use of significant digits. Transfer from mathematics to chemistry was calculated using designated problems from the final examinations in both mathematics and chemistry as well as chapter tests in mathematics.

Each student received a score from zero to four on each type of problem in mathematics and a score from zero to four on each mathematical type of problem on the chemistry final examination. For each student, a correct response in MA070 on a majority (three of four, or two of three) of the items of a particular type of problem indicated attainment of mathematical skill (success) on that type of problem. For each student, a correct response in CH104 on at least three of the four designated problems of a particular type indicated attainment of the mathematical skill in chemistry (success) on that type of problem. Success in mathematics followed by success in chemistry on the same mathematical type of problem indicated transfer on that type.

Student Attitudes and Anxiety Levels. Attitudes about mathematics and anxiety in dealing with mathematical topics were assessed for each student in the mathematics class using instruments developed by Oxreider and Ray (1982). Copies of these survey instruments appear in Appendix C. On the 20 item true/false "Math Attitude Survey," a high numerical score (15-20) indicates a relatively accurate view of the role of mathematics and how it is learned. A low score (0-8) indicates a relatively inaccurate view of the subject. On the "Math Anxiety Scale" students rate a list of 25 items on a scale from one to three, with one being "not at all anxious" and three being "very anxious." A high score (63-75) indicates a significant amount of math anxiety while a low score (25-37) indicates very little math anxiety. The "Math Attitude Survey" and "Math Anxiety Scale" were given on the first and last days of the MA070 classes in both the control and experimental groups. Mean test scores from the pre- and post-tests were compared for the control and the experimental groups to determine if any effect from the treatment was present.

CHAPTER IV

DATA ANALYSIS AND FINDINGS

The purposes of this study included examination of curricular and instructional integration of mathematics and the sciences to see if it would lead to increased transfer of learning from mathematics to chemistry as well as greater achievement in both mathematics and chemistry. In addition, the study examined student attitudes towards mathematics and anxiety levels about mathematics both at the beginning and at the end of the mathematics semester. To accomplish this purpose, the study compared achievements in mathematics and chemistry as well as transfer of learning from mathematics to chemistry for students taught basic mathematics/ elementary algebra in two different ways. The study compared attitudes towards mathematics and anxiety levels about mathematics between the two groups at the beginning and at the end of the semester. The study also compared the attitude towards mathematics and the anxiety levels within each group from the beginning to the end of the semester. Chapter IV details the analysis and findings of the study. It begins with a comparison of the Academic Assessment Placement Program (AAPP) test scores for the control and experimental groups, and then reports the results that the curricular changes had on remedial mathematics students who took MA070 in Fall 1991 and CH104 in Spring 1992, in terms of the hypotheses guiding the study, with a discussion of the statistical processes used to test each hypothesis.

Underlying this study was the assumption that the experimental and the control groups had similar mathematical deficiencies and skills as measured by the AAPP test used by Tennessee Board of Regents schools to measure entry level skills in mathematics. Using the Student's t distribution, there was no statistical evidence at the 0.05 level of significance to suggest different levels of preparation in mathematics between the two groups. However, as indicated in Table 4.1, the p value of 0.056 does approach significance.

TABLE 4.1 Mean Scores on AAPP test

Group	n	Mean	S.D.	t score	p value
Experimental	14	17.29	3.79	1.99	0.056
Control	18	20.06	4.01		

Hypothesis I: There will be no difference in achievement in basic mathematics and elementary algebra for students who complete an experimental basic mathematics/elementary algebra course designed to use a calculator extensively and to integrate mathematics and science than for students who complete a standard basic mathematics/elementary algebra course.

Twenty-five students began the experimental class of MA070. Of those, 14, or 56%, finished the course with a grade of C or better. In the control class, in which the use of the calculator was not emphasized and in which no particular effort was made to integrate mathematics and science, 23 students were originally enrolled. Of that number, 18, or 78%, completed the course with a grade of C or better. Statistical analyses were based on the students who actually completed MA070.

The first two measures of mathematics achievement used were the mean scores on the final exams in mathematics and the mean final averages in mathematics. Using the Student's t distribution, no statistical support at the 0.05 level of significance was found to reject the null hypothesis. Tables 4.2 and 4.3 provide detailed information about these measures.

TABLE 4.2 Mean Scores on Mathematics Final Exams

Group	n	Mean	S.D.	t score	p value
Experimental	14	84.64	8.63	-0.03	0.49
Control	18	84.56	7.69		

TABLE 4.3 Mean Final Averages in Mathematics

Group	n	Mean	S.D.	t score	p value
Experimental	14	89.64	5.26	-1.44	0.08
Control	18	86.91	5.36		

The third measure of mathematics achievement was calculated using the mean scores on the mathematics diagnostic tests given in chemistry. The sample sizes for this measure differed from the first two measures of achievement because some students elected not to take CH104 the following semester. Using the Student's t distribution, no statistical support at the 0.05 level of significance was found to reject the null hypothesis. Table 4.4 provides detailed information about this measure.

TABLE 4.4 Mean Scores for Mathematics Diagnostic Test in Chemistry

Group	n	Mean	S.D.	t score	p value
Experimental	9	41.22	9.00	0.59	0.28
Control	10	44.30	13.00		

The experimental group showed no significant difference from the control group on any of the three measures of achievement. Therefore, according to the measures of mathematics achievement used in this study, Hypothesis I cannot be rejected.

Hypothesis II: There will be no difference in achievement in basic chemistry for students who complete an experimental basic mathematics/elementary algebra course designed to use a calculator extensively and to integrate mathematics and science than for students who complete a standard basic mathematics/elementary algebra course.

Of the 14 students who completed the experimental mathematics course, 9 enrolled the subsequent semester in CH104. Of the 18 students who completed the control mathematics course, 11 enrolled in CH104 the subsequent semester.

The measures of chemistry achievement used were the mean scores on the final exams in chemistry and the mean final averages in chemistry. Using the Student's t distribution, no statistical support at the 0.05 level of significance was found to reject the null hypothesis. Tables 4.5 and 4.6 present this information.

TABLE 4.5 Mean Scores on Chemistry Final Exams

Group	n	Mean	S.D.	t score	p value
Experimental	9	69.80	13.70	1.06	0.15
Control	11	75.18	9.10		

TABLE 4.6 Mean Final Averages in Chemistry

Group	n	Mean	S.D.	t score	p value
Experimental	9	83.78	7.17	0.90	0.19
Control	11	86.0	3.92		

The experimental group showed no significant difference from the control group on any of the measures of achievement. Therefore, according to the measure of chemistry achievement used in this study, Hypothesis II cannot be rejected.

Hypothesis III: There will be no difference in transfer of mathematical skills for selected isomorphic topics in basic mathematics/elementary algebra and basic chemistry for students who complete an experimental basic mathematics/elementary algebra course designed to use a calculator extensively and to integrate mathematics and science than for students who complete a standard basic mathematics/elementary algebra course.

Of the 9 experimental students who enrolled the subsequent semester in CH104, 9 finished the course. Of the 11 control students who enrolled the subsequent semester in CH104, 11 finished the course.

The measures of mathematics transfer to chemistry were the successful completion of mathematics problems in chemistry after the students demonstrated that ability in MA070. The four topics that were examined were solving proportion and percentage problems, manipulating formulas, making conversions, and understanding scientific notation and significant digits. Through attrition, the sample sizes in both groups were less than half the size of the original groups starting MA070. This fact meant that it was impossible to collect data on a large enough sample for each topic to make any judgement concerning Hypothesis III. The raw data for each group by topic can be found in Appendix D. The appropriate test using the normal distribution to compare proportions could not be used due to this small sample size.

Hypothesis IV: There will be no difference in attitude toward mathematics for students who complete an experimental basic mathematics/elementary algebra course designed to use a calculator extensively and to integrate mathematics and science than for students who complete a standard basic mathematics/elementary algebra course.

A mathematics attitude survey was administered to both groups of students during the first week of class. The Student's t distribution was used to compare the mean scores. There was no significant difference at the 0.05 level between the control and experimental groups initially. The same attitude survey was administered at the end of the semester with the same results. Using the Student's t distribution, no statistical support at the 0.05 level of significance was found to reject the null hypothesis. In addition, the Student's t distribution was used to see if there was a difference in attitudes within each group from the beginning to the end of the semester. No change in attitude at the 0.05 level of significance was found in either group. The results are presented in the Table 4.7.

TABLE 4.7 Attitudes Toward Mathematics

Group	n	Pre-test Mean	Pre-test S.D.	Post-test Mean	Post-test S.D.	t score	p value
Experimental	14	10.57	2.41	10.86	1.75	-0.36	0.36
Control	18	10.11	1.88	10.67	1.97	-0.87	0.20
Across groups				Pre-test Post-test		-0.62 -0.28	0.55 0.39

Hypothesis V: There will be no difference in anxiety toward mathematics for students who complete an experimental basic mathematics/elementary algebra course designed to use a calculator extensively and to integrate mathematics and science than for students who complete a standard basic mathematics/elementary algebra course.

A mathematics anxiety survey was administered to both groups of students during the first week of class. The Student's t distribution was used to compare the mean scores. There was no significant difference at the 0.05 level between the control and experimental groups initially. The same anxiety survey was administered at the end of the semester with the same results. Using the Student's t distribution, no statistical support at the 0.05 level of significance was found to reject the null hypothesis. In addition, the Student's t distribution was used to see if there was a difference in anxiety levels within each group from the beginning to the end of the semester. Both groups showed a significant decrease in anxiety towards mathematics. The results are presented in the Table 4.8.

TABLE 4.8 Anxiety Levels Towards Mathematics

Group	n	Pre-test Mean	Pre-test S.D.	Post-test Mean	Post-test S.D.	t score	p value
Experimental	14	46.00	7.32	36.86	5.29	3.79	0.0004
Control	18	47.33	9.62	41.56	9.61	1.80	0.040
Across groups				Pre-test Post-test		0.43 1.64	0.67 0.055

Summary of Results

No significant difference at the 0.05 level was found in the achievement in basic mathematics and elementary algebra for students completing the experimental mathematics course as compared to those students completing a standard mathematics course. No significant difference at the 0.05 level was found in achievement in basic chemistry for students completing the experimental mathematics course as compared to those students completing a standard mathematics course. No judgement could be made concerning the transfer of specific topics in mathematics to chemistry for the experimental and control groups because, after attrition, the resulting sample size was too small to be statistically analyzed. No significant difference at the 0.05 level in attitude toward mathematics was discovered between the two groups, nor was there a significant difference at the 0.05 level found between the pre-test scores and the post-test scores of either group. No significant difference in anxiety level toward mathematics was found between the two groups. However, student anxiety levels decreased significantly in both groups during the mathematics semester.

CHAPTER V

SUMMARY, DISCUSSIONS, CONCLUSIONS, AND RECOMMENDATIONS

This chapter presents a summary, discussion, and the conclusions of the study. In addition, limitations of this study and recommendations for further research are discussed.

Summary of the Study

Because of the continuing emphasis in the literature on integration of curricula to encourage transfer of learning, an experimental study was designed to determine if curricular and instructional integration of mathematics and science would encourage transfer of learning from mathematics to chemistry, greater achievement in algebra and chemistry, more positive attitudes towards mathematics, and lessened anxiety levels towards mathematics. The study was conducted at Chattanooga State Technical Community College (CSTCC) during the 1991-92 academic year. Students who expressed an interest in nursing or another allied health field requiring CH104, Principles of Chemistry, and who were required to enroll in MA070, Basic Mathematics/Elementary Algebra, were enrolled in one of two designated mathematics sections taught by the researcher. One section of MA070 was used as the control group and the other as the experimental group. The students who completed one of the two designated sections of MA070 during the 1991 fall semester and who completed CH104 during the 1992 spring semester became the subjects of the study. The control group was taught algebra and basic mathematics using a traditional approach, with no particular steps being taken to integrate mathematics and the sciences and without use of the calculator. The experimental group was taught with a curriculum designed to use the calculator extensively and to encourage integration of mathematics and the sciences and, therefore, transfer of learning from mathematics to chemistry.

Achievement in mathematics and chemistry was calculated for each student for each of the courses based on student final examination results and final grade averages. Mean test scores for both the control and experimental groups were gathered from the mathematics final examination, the departmental mathematics diagnostic test given in the chemistry course to ascertain readiness for chemistry, and a teacher-made chemistry final examination. Mean final grade averages in both mathematics and chemistry were computed. Transfer from mathematics to chemistry was calculated using designated problems from the final examinations in both mathematics and chemistry as well as chapter tests in mathematics. Success in mathematics followed by success in chemistry on the same mathematical type of problem indicated transfer on that type. Finally, attitudes about mathematics and anxiety in dealing with mathematical topics were assessed for each student in the mathematics class using instruments developed by Oxreider and Ray (1982). Mean test scores from pre- and post-tests were used two ways: (1) to determine if any effect from the treatment appeared within an individual group and (2) to compare differences in student perceptions between the control and experimental groups. These data were analyzed to see if there were any differences between the control and the experimental groups on any of the measures. In order to determine whether the results were statistically significant, analyses were made using the Student's t distribution.

Summary of the Findings

The study determined that for these students, at this time, a basic mathematics/elementary algebra course designed to use a calculator extensively and to integrate mathematics and science made no difference in either mathematics achievement or in chemistry achievement, as measured by final examination and final grade averages. Concerning the transfer of mathematical skills and problem solving ability from the mathematics class to a subsequent chemistry course as reflected in student test results, no judgement could be made, because insufficient data were collected. No difference was found in attitudes towards mathematics and in anxiety levels towards mathematics between the control and experimental groups. At the 0.05 level, however, there was a significant reduction in anxiety level within both groups during the semester.

Discussion

The major question for this study was whether significant improvement in mathematics and chemistry achievement could be obtained by integrating the two curricula, and encouraging transfer of learning from mathematics to chemistry. Three hypotheses were used to test this question. A secondary focus of the study involved student perceptions towards mathematics, and two hypotheses were used to test this focus. The ensuing discussion is organized according to these five hypotheses with general observations following.

Mathematics Achievement. No significant difference in mathematics achievement between the experimental and the control groups was found. This fact appears to suggest that differences in curricular approaches made no difference in mathematics achievement. However, other factors must be examined before such a conclusion can be drawn.

One factor might be that there was no real difference between the two curricular approaches for the control and the experimental groups. Application problems were designed for the experimental group in consultation with chemistry, anatomy and physiology, nutrition, and nursing instructors. The problems presented illustrated to the students how selected topics would be used in those fields. No such application problems were provided for the control group. Totally different approaches were used: concrete to abstract with the experimental group, abstract to concrete with the control group. Also, because calculators were required in chemistry, the experimental group received instruction in effective calculator use, were encouraged to use calculators in class and for homework, and were allowed to use calculators on all tests. The control group did not receive instruction on calculator usage, did not use calculators in class, and were not permitted to use calculators on tests. Therefore, there were real differences in the curricular approach to the classes. There is strong support in the literature for the idea that such an approach, which emphasizes calculator usage and integration of mathematics and science topics, should make a difference in achievement, but there has been little empirical research done to verify this assumption. Certainly the researcher expected greater achievement in the experimental group using the integrated curriculum.

Another possible reason for the lack of difference in achievement between the groups might be that they began the courses with significant differences in mathematical preparedness for MA070 that were not detected by the Academic Assessment Placement Program (AAPP) test. The mean score for the experimental group on the AAPP Mathematics Test was lower than that of the control group by nearly three points (see Table 4.1), a significant difference at the 0.10 level although not at the 0.05 level chosen for this study. (The p-value was 0.056.) Further, a higher percentage of students from the experimental group did not complete MA070 (44% versus 22%). There may have been personal reasons for the difference in noncompletion rates between the groups unrelated to mathematical ability, but the researcher's personal perceptions of the two classes support the idea that the experimental group was weaker mathematically. If it is true that the experimental group was weaker in entry level mathematical skills, then the fact that there was no significant difference in mathematical achievement at the end of the semester may mask the effects of the experimental curriculum on learning. Indeed, it may be that the experimental group "caught up" to the control group, actually learning more with the experimental curriculum. In fact, the mean final average in mathematics was higher for the experimental group by nearly three points, a significant difference at the 0.10 level although not at the 0.05 level chosen for this study, thus lending modest support to this contention. (The p-value was 0.08.)

Chemistry Achievement. Although an integrated mathematics curriculum using calculators was expected to improve achievement in chemistry, there was no significant difference in chemistry achievement between the experimental and the control groups. Since the link between mathematics achievement and science achievement is one of the assumptions on which this study was based, the lack of difference in chemistry achievement is an expected result, given that there was no significant difference in mathematics achievement. Indeed, had the students shown significant chemistry achievement but no difference in mathematics achievement, a basic premise of the study would be questioned.

Transfer. Using specific mathematical topics that were applicable to the chemistry course, the researcher expected to test whether skill on a particular topic achieved in mathematics had transferred to the chemistry course. Because of attrition throughout the two semesters, there was not a large enough sample size to submit to the appropriate statistical test. The attrition through the fall semester in MA070 as well as the failure of all students who completed mathematics to enroll in CH104 in the spring resulted in a low completion rate from initial mathematics enrollment to completion of chemistry; 36% (9) of the initial experimental group and 48% (11) of the initial control group completed chemistry. Part of the difference in completion rates might be due to the possible weaker preparation mentioned earlier, but that is only speculation. Such small numbers made any data concerning transfer of mathematical topics to applications in chemistry statistically irrelevant. This area of transfer of learning of specific topics from one course to another is an area where further empirical research is needed.

Attitude. There was no significant difference between the two groups concerning their attitudes toward mathematics either at the beginning or at the end of the fall semester. In addition, neither group showed a significant change in attitude during the semester. On that basis, one might conclude that the experimental curriculum made no difference in attitude during the semester within the groups or between the two groups. Since the subjects were remedial mathematics students, one might expect their attitudes towards mathematics to be relatively negative, because they were retaking subject matter they had previously failed to master, subject matter that is part of every elementary school curriculum. It is difficult to imagine much measurable change in an attitude acquired over many years to occur in three months. Thus, the results are not surprising. However, attendance in the experimental group was better than in the control group, and students in the experimental group appeared to be more interested in the course. The students' attendance and interest may indicate that the experimental group recognized the relevance of the course, though there is no empirical proof to support such a conclusion.

Anxiety. There was no significant difference between the two groups concerning their anxiety level toward mathematics either at the beginning or at the end of the fall semester. Both groups experienced a moderate amount of mathematics anxiety as defined by the survey instrument at the beginning of the semester. Although there was not a significant difference between the anxiety levels of the two groups at the end of the semester, the experimental group's anxiety level had dropped from the moderate to the very little range of anxiety level. Although the control group showed a significant change in anxiety level during the semester, their anxiety level remained in the moderate range. The experimental group also showed a significant decrease in anxiety level from the beginning to the end of the semester.

Since the subjects were remedial mathematics students, one might expect their anxiety level towards mathematics to be relatively high. It was surprising to the researcher that the initial anxiety level of both groups was not higher. An examination of the individual surveys revealed inconsistencies in the responses to the questions, such as the student who rated himself very anxious when adding whole numbers (35+22=) but not at all anxious when solving an equation (3x+7x=25-2x) or doing his income tax. Reasons other than the students' perceptions which might have led to such inconsistencies could include inability to understand directions, lack of understanding of the items, or indifference to the survey. Certainly such inconsistencies indicate that the survey instrument may not have revealed anxiety levels correctly for all students. Thus, further investigation in this area is needed to either support or refute the results of this study regarding student anxiety level.

General observations. Although persistence in school was not considered in the hypotheses, it is interesting to note that of the nine students in the experimental group who completed chemistry in the spring 1992 semester, six of them are still in school in the spring 1994 semester and still pursuing allied health careers. Of the eleven students in the control group who completed chemistry in the 1992 spring semester, six of them are still in school in the spring 1994 semester and four are still pursuing allied health careers. Although such small numbers make any speculation regarding reasons for persistence statistically irrelevant here, it does suggest that efforts to stress relevance and transfer of material from mathematics to other courses might result in greater student perseverance.

The impetus for this study was the indication in the literature that mathematical instruction should be connected to other disciplines to improve achievement in both mathematics and the other discipline. There has been little research done to support this idea, particularly in chemistry. The idea for using chemistry as the second discipline grew from complaints from chemistry instructors that their students were unable to perform mathematical operations, operations which the students should have learned in the previously taken mathematics course. Although this study does not provide results demonstrating the efficacy of this instructional approach in improving achievement and in transfer of learning, it has raised questions about the approach and about transfer of mathematics learning to chemistry, and therefore should provide a base for further research.

Other factors may have influenced the results of this study. Certainly the sample size was too small, given the attrition that occurred. The smaller the sample size the more difficult it is to reject any null hypothesis using the Student's t distribution. The testing of the transfer of skills from mathematics to chemistry could not even be performed because of the small sample size. Another factor may be that one semester was not an adequate time frame to assimilate new approaches to learning mathematics, nor to make significant changes in student attitude and anxiety levels, because learning habits and perceptions about mathematics had long been established in these adult students. Also, the researcher assumed, based on AAPP test results, that the two classes were roughly equivalent in mathematical skills, but they may not have been in actuality. Certainly these factors, discovered in this first study of curricular integration of mathematics and science, should be considered in designing other studies. From the results of this study no firm conclusions can be drawn. However, the study points out pitfalls to be avoided in further, similar research and demonstrates that educators should be careful of broad assumptions, even if such assumptions appear logical. Certainly, given present learning theory, it was reasonable to expect differences in achievement and transfer. Since these differences did not appear, there are either other factors which were not sufficiently considered (e.g., attrition and entry level skills) or the assumptions throughout the literature are erroneous.

Conclusions

Literature supporting integration of mathematics and the sciences presently upholds the idea that integration of the two curricula will increase transfer of learning and achievement in both areas. Although widely accepted, these opinions expressed in the literature have not been sufficiently tested empirically. This study attempted to begin filling that void.

This study cannot support these widely held opinions. However, this study alone does not disprove these opinions either. It is indeed premature to draw any conclusions. As with any statistical study, many factors may have affected the outcomes, as has been previously discussed. It is important to recognize that, as is true of most first studies in a particular area of interest, determining which other factors may affect results provides a valuable information base for the next researcher.

Recommendations for Further Study

Research studies not only support or fail to support hypotheses, but they also clarify issues and ways to study issues. Such has been the case with this one. Although this study did not provide concrete conclusions concerning the efficacy of the experimental curricular design, it did illustrate the need for further research in this area. Since the lack of concrete conclusions may not be related to the hypotheses or to the design, this study should be replicated with the same design but with a larger initial sample size. These replications will provide evidence to prove or disprove whether integrating mathematics and science curricula encourages transfer of learning and achievement in both subjects. Further, this study could be replicated with different application topics and different science courses as well, in order to determine if specific subject matter affects transferability. An attempt to design a similar study integrating mathematics and sciences for higher level mathematics courses would also be useful to determine if complexity of topics and/or mathematical maturity affects transferability. Such a study might eliminate factors (e.g., lack of previous success in mathematics) peculiar to developmental students which might have influenced results. It is recommended that two studies be conducted with the integrated science curriculum as the variable, one with both the control and the experimental groups using the calculator and one with neither group using the calculator. These two studies would test the role of the calculator as a part of the integrated curriculum. Certainly, future study of the effect of such an experimental curriculum on mathematics achievement, on chemistry achievement, and on transfer of learning is needed. The literature contains many opinions about transfer of learning and its effect on achievement; empirical studies to prove or disprove these opinions are needed.

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APPENDICES

APPENDIX A

RECRUITMENT MATERIAL

ARE YOU INTERESTED IN AN ALLIED HEALTH FIELD?

NURSING?

Do you need MA 070 and CH 104?

WE HAVE TWO SPECIAL MATH SECTIONS FOR YOU

THIS FALL:

TAKE MA 070-04 DAILY 10:30 - 11:30 AM

OR

MA 070-11 DAILY 9:20 - 10:20 AM

SPRING SEMESTER:

TAKE MA 080 AND CH 104

CALL GLADYS CRATES AT #260 FOR FURTHER DETAILS

APPENDIX B

CONSENT FORM

CHATTANOOGA STATE TECHNICAL COMMUNITY COLLEGE

Chattanooga, Tennessee

TO: Students taking MA 070-04 and MA 070-11 during the Fall semester 1991

FROM: Gladys Crates, Director of Project for investigating Changes in Curricula Design and the Effect on Transfer of Learning in Developmental Mathematics Students

The purpose of this letter is to request your participation in a project that would allow me to use some of the following information about you:

1. AAPP Mathematics test score
2. Chattanooga State Mathematics diagnostic test
3. Mathematics test scores
4. Chemistry diagnostic test
5. Chemistry test scores
6. Mathematics anxiety test scores
7. Mathematics attitude test scores
8. Final numerical grade in MA 070 and CH 104

The purpose of this project is to examine if curricular and instructional integration of mathematics and the sciences lead to increased transfer of learning from mathematics to chemistry as well as greater achievement in algebra and chemistry. As a result of this study, we hope to establish strategies which encourage transfer of learning from mathematics to chemistry.

The summary data from this study will be used in my Doctoral dissertation. Only I will have access to the data collected and it will be kept in strict confidence. In fact, after all the data have been collected, the name and social security number of each person will be removed from the data.

I would appreciate your cooperation in this project; however, I will use the data on you only if you volunteer for me to do so. Using, or not using, data on you will in no way affect your grade in the course. Even though you may initially volunteer for me to use the data on you, you may withdraw this consent and withdraw from the project at any time without prejudice. I will be glad to answer any of your questions about this project.

If you agree to participate in the project as described above, please sign your name below.

____

NAME

APPENDIX C

SURVEY INSTRUMENTS

EXERCISE: <u>MATH ANXIETY SCALE</u>

Directions: On the scale below, rate yourself according to how anxious you do feel (or would expect to feel) in these math situations. Circle the number which best describes your feelings:

1. not at all anxious
2. a little anxious
3. very anxious

1.	When I count out change.	1	2	3
2.	When I have to balance my checkbook.	1	2	3
3.	When I figure out my gas mileage.	1	2	3
4.	When I have to determine a tip.	1	2	3
5.	When I must use metric measurements.	1	2	3
6.	When I'm trying to figure out if I brought enough money to cover the groceries I'm buying.	1	2	3
7.	When I add whole numbers (35+22=?).	1	2	3
8.	When I subtract whole numbers (35-22=?).	1	2	3
9.	When I multiply whole numbers (35x22=?).	1	2	3
10.	When I divide whole numbers (35/22=?).	1	2	3
11.	When I have to do a problem involving fractions.	1	2	3
12.	When I have to do a problem where you work with percents or decimals (5% of $25.95).	1	2	3

13.	When I try to solve a word (story) problem.	1	2	3
14.	When I try to solve an equation (3x+7x=25-2x).	1	2	3
15.	When I try to work a geometry problem.	1	2	3
16.	When I read the titles of math courses in a college catalog.	1	2	3
17.	When I walk into a math class.	1	2	3
18.	When I take a math test.	1	2	3
19.	When I do my income tax.	1	2	3
20.	When I have to do a math homework assignment	1	2	3
21.	When I look at a math textbook.	1	2	3
22.	When I try to read a math textbook	1	2	3
23.	When I see math symbols I don't know.	1	2	3
24.	When I try to use a calculator.	1	2	3
25.	When I try to understand a graph.	1	2	3

<u>Scoring:</u> Now total up the circled numbers. If your score is:

25 - 37 you currently experience very little math anxiety

38 - 62 you experience a moderate amount of math anxiety

63 - 75 you experience a significant amount of math anxiety

EXERCISE: <u>MATH ATTITUDE SURVEY</u>

Directions: Respond to each of the following statements by deciding whether you believe it is true (T) or false (F). Answer according to your personal attitudes rather than what you think should be the case.

____ 1. People who can do mental arithmetic (adding numbers in their head without using pencil and paper) usually have little trouble in math classes.

____ 2. People who are good in math are orderly and rational types.

____ 3. Mathematicians are often dull and/or eccentric.

____ 4. People who are good in math often cannot do problems very quickly.

____ 5. Some people have the ability to do mathematics and others just don't.

____ 6. Men are better in math than women.

____ 7. Women are better in math than men.

____ 8. Mathematicians are often poor in elementary subjects like arithmetic and algebra.

____ 9. Doing math consists of learning a complicated set of rules.

____ 10. The ability to memorize these rules is extremely helpful in learning math.

____ 11. People who are good in math can solve new problems relatively easily.

_____ 12. Math is a creative activity, much like writing music or painting a picture.

_____ 13. Studying a new topic in math is always hard work.

_____ 14. If someone has trouble doing simple math problems, they will never be able to do the more difficult ones.

_____ 15. About 25% of the population suffers from some form of math anxiety.

_____ 16. Children who are allowed to use calculators in learning arithmetic will learn it better.

_____ 17. If you've had trouble doing math in the past, you will continue to have trouble in the future.

_____ 18. Guessing at answers to math questions is improper since there is usually only one right answer.

_____ 19. The ability to understand mathematical reasoning is important in every day life.

_____ 20. Solving a math problem is a satisfying activity.

Scoring: Score one point each if you answered True to: 4, 8, 12, 13, 16, 19, and 20.

Score one point each if you answered False to: 1, 2, 3, 5, 6, 7, 9, 10, 11, 14, 15, 17, and 18.

A high score (15-20) indicates a relatively accurate view of the role of math and how it is learned. A low score (0-8) indicates a relatively inaccurate view of the subject. A middle score (9-14) is average.

APPENDIX D

TRANSFER OF LEARNING

RAW DATA

RAW DATA FOR MEASURING TRANSFER

FROM MATHEMATICS TO CHEMISTRY

TABLE D.1 Control Group

ID #	Proportions/ Percentages (4/4) *	Formula Manipula-tion (4/4) *	Conversions (4/4) *	Scientific Notation/ Significant Digits (3/4) *
1	3/2/N	4/4/Y	4/4/Y	3/3/Y
2	4/3/Y	4/3/Y	4/3/Y	3/3/Y
3	3/2/N	3/3/Y	3/4/Y	2/4/Y
4	2/0/N	4/1/N	4/3/Y	3/4/Y
5	4/2/N	4/3/Y	4/3/Y	1/4/N
6	3/2/N	4/3/Y	4/2/N	3/1/N
7	2/1/N	2/1/N	4/1/N	2/2/N
8	3/2/N	4/3/Y	4/2/N	1/2/N
9	3/2/N	3/3/Y	4/3/Y	1/4/N
10	4/1/N	4/2/N	4/2/N	2/3/Y
11	2/1/N	3/3/Y	4/3/Y	2/4/Y

* Math score followed by chemistry score with perfect score in parentheses; Y or N indicates yes or no for transfer as outlined in Chapter III.

TABLE D.2 Experimental Group

ID #	Proportions/ Percentages (4/4) *	Formula Manipulation (4/4) *	Conversions (4/4) *	Scientific Notation/ Significant Digits (3/4) *
1	4/2/N	4/2/N	4/3/Y	3/3/Y
2	4/1/N	4/0/N	3/1/N	0/3/N
3	3/1/N	4/1/N	2/2/N	2/2/N
4	2/3/N	4/3/Y	4/2/N	3/1/N
5	2/2/N	4/2/N	4/2/N	2/2/N
6	3/2/N	4/4/Y	4/3/Y	3/1/N
7	3/1/N	2/1/N	2/1/N	2/2/N
8	4/3/Y	4/4/Y	4/4/Y	3/4/Y
9	4/1/N	4/3/Y	3/1/N	3/4/Y

* Math score followed by chemistry score with perfect score in parentheses; Y or N indicates yes or no for transfer as outlined in Chapter III.

VITA

Gladys Hayes Crates was born in Kingston, Ontario, Canada, on February 15, 1943. She graduated from high school in Cincinnati, Ohio, in 1960. In the fall of that year she entered Duke University in Durham, North Carolina, which she attended for two years. In 1969 she entered the University of Tennessee in Chattanooga and in 1971 received a Bachelor of Arts Degree in Mathematics with Honors. The degree of Master of Science in Mathematics was conferred in 1973 from the University of Tennessee. This dissertation completes requirements for an Ed.D. in Education at the University of Tennessee in Knoxville, Tennessee.

Ms. Crates has taught mathematics at Chattanooga State Technical Community College in Chattanooga, Tennessee, since 1974. She has taught both developmental and college level mathematics.

At the present time, Ms. Crates is the Dean of Mathematics and Sciences at Chattanooga State Technical Community College, a position she has held since 1986.