



Effect of the use of an Internet-based problem of the week on high school geometry student problem-solving achievement and attitudes toward mathematics  
by Clifford P Goudelock

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

This research studied the effect of using Swarthmore College's Math Forum geometry Problem of the Week (POW), an Internet-based learning resource, on high school student problem-solving achievement and attitudes toward mathematics. The study was designed to determine if student access to the Internet during the time allowed for solving the Problem of the Week had a greater effect on their problem-solving achievement than the effect on students who did not have access to the Internet. Of additional importance in this study was the effect that using Internet-based learning resources had on the attitudes toward mathematics of all student participants in the study and the effect of gender on both mathematics achievement and attitudes toward mathematics.

The study was conducted from March, 1998 through May, 1998. Participants included three Montana high school geometry teachers, each of whom taught two sections of geometry for the spring semester, and the students enrolled in each of these sections. Through a random process, one of the two sections taught by each of the participating teachers was designated the experimental group, and they received access to the Internet during the time allowed each week to solve the POW. The other section taught by each teacher was designated the control group, and they did not receive access to the Internet during the time allowed each week for solving the POW. Two Montana high schools were involved in the study. A basic geometry knowledge test and a mathematics attitude inventory were administered to participating students before treatment. Each week for ten weeks, participating students attempted to solve the POW, and their solutions were assessed. The average of the scores on these ten weekly solutions was one of the criteria used to determine student problem-solving achievement (WK10AV). A problem-solving test and the same mathematics attitude inventory given at the beginning of the study were administered to all participating students after ten weeks of attempting to solve the POW.

Analysis of variance was used to test for differences in the basic math knowledge of participants in the experimental and control groups before treatment, to test for differences in attitudes due to treatment and gender before and after treatment, and to test for differences in problem-solving achievement after treatment. Analysis of covariance was used to determine the effect that the amount of time the experimental group utilized access to the Internet had on their problem-solving achievement.

On the basis of this analysis, the researcher concluded that access to the Internet during the solution of the POW did not have an effect on student problem-solving achievement. Before treatment, there was a difference in the self-concepts of the female and male participants in the control group, with the female participants scoring lower. After treatment, there was no difference in female and male self-concepts toward math.

EFFECT OF THE USE OF AN INTERNET-BASED "PROBLEM OF THE WEEK"  
ON HIGH SCHOOL GEOMETRY STUDENT PROBLEM-SOLVING  
ACHIEVEMENT AND ATTITUDES TOWARD MATHEMATICS

by

Clifford P. Goudelock

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

of

Doctor of Education

MONTANA STATE UNIVERSITY - BOZEMAN  
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APPROVAL

of a thesis submitted by

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

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I dedicate this dissertation to my Mother, Linda P. Goudelock, of Lyons, Colorado. Without her undying support and devotion, I would never have been able to achieve many of my lifetime goals and dreams. Her inspiration and strength will live in me forever.

## VITA

Clifford Pittman Goude-lock was born on October 28, 1949, in Cleveland, Mississippi, the son of Linda Young Pittman and James M. Goude-lock. He attended Cleveland Public Schools, Cleveland, Mississippi, and graduated from Cleveland High School in 1967.

He received a Bachelor of Science in Education degree with a major in mathematics and a minor in Science from Delta State University, Cleveland Mississippi, in 1972, and a Master of Science in Education degree with a major in mathematics from the same institution in 1973.

After completion of his Master's degree, he moved to Montana, where he taught high school mathematics and science for seven years. From 1981 through 1984 he worked as a NASA certified flight controller at the University of Colorado in Boulder, commanding flight of the Solar Mesosphere Explorer, a satellite used to study the ozone layer around the Earth.

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## ABSTRACT

This research studied the effect of using Swarthmore College's Math Forum geometry Problem of the Week (POW), an Internet-based learning resource, on high school student problem-solving achievement and attitudes toward mathematics. The study was designed to determine if student access to the Internet during the time allowed for solving the Problem of the Week had a greater effect on their problem-solving achievement than the effect on students who did not have access to the Internet. Of additional importance in this study was the effect that using Internet-based learning resources had on the attitudes toward mathematics of all student participants in the study and the effect of gender on both mathematics achievement and attitudes toward mathematics.

The study was conducted from March, 1998 through May, 1998. Participants included three Montana high school geometry teachers, each of whom taught two sections of geometry for the spring semester, and the students enrolled in each of these sections. Through a random process, one of the two sections taught by each of the participating teachers was designated the experimental group, and they received access to the Internet during the time allowed each week to solve the POW. The other section taught by each teacher was designated the control group, and they did not receive access to the Internet during the time allowed each week for solving the POW. Two Montana high schools were involved in the study

A basic geometry knowledge test and a mathematics attitude inventory were administered to participating students before treatment. Each week for ten weeks, participating students attempted to solve the POW, and their solutions were assessed. The average of the scores on these ten weekly solutions was one of the criteria used to determine student problem-solving achievement (WK10AV). A problem-solving test and the same mathematics attitude inventory given at the beginning of the study were administered to all participating students after ten weeks of attempting to solve the POW.

Analysis of variance was used to test for differences in the basic math knowledge of participants in the experimental and control groups before treatment, to test for differences in attitudes due to treatment and gender before and after treatment, and to test for differences in problem-solving achievement after treatment. Analysis of covariance was used to determine the effect that the amount of time the experimental group utilized access to the Internet had on their problem-solving achievement.

On the basis of this analysis, the researcher concluded that access to the Internet during the solution of the POW did not have an effect on student problem-solving achievement. Before treatment, there was a difference in the self-concepts of the female and male participants in the control group, with the female participants scoring lower. After treatment, there was no difference in female and male self-concepts toward math.

## CHAPTER 1

## PROBLEM STATEMENT AND REVIEW OF THE LITERATURE

Introduction

The use of traditional geometry textbooks by mathematics teachers nationwide sometimes has a limiting effect on the geometry problem-solving exposure and practical problem-solving experience gained by high school students. With the coming of the Technological Age, there are new ways for teachers and students to access relevant, current, and interesting learning resources which can help build problem-solving skills. The Internet is one location where new learning resources can be found. The Math Forum Problem of the Week (POW), one of these new learning resources, is provided by Swarthmore College via the Internet. Another learning resource available through the Math Forum is the Archives, which contain solutions to the POW's from the previous four years. Both of these resources, along with communication between students trying to solve the POW via E-mail, could be used to motivate and interest teachers and their students who might not be exposed to the problem-solving skills needed in their future careers.

Examples of the need for problem-solving skills have been documented from the earliest days of recorded history. The great pyramid of Gizeh was erected about 2900 B.C., and undoubtedly required mathematical and engineering skills (Eves, 1969). The oldest extant astronomical calculations date from 1850 B.C., and the Rhine Papyrus, which contains 85 mathematical problems, was written about 1650 B.C. Interestingly, the

symbol for the number zero (0) was not documented until around 825 B.C. Certainly origin of a symbol for zero was a mathematical problem whose solution was of paramount importance. Ancient mathematical problems involved construction calculations, solutions for commerce accounting, and methods for recording and distributing the assets of societies (Eves, 1969).

Problem-solving skills are needed across all educational disciplines. Composing the music for a song, building a birdhouse in an Industrial Arts class, baking a cake, and writing an essay all involve procedures that demand organization and continuity. Success in mathematics requires a variety of problem-solving skills. Instruction in mathematics must be planned to maximize each student's interaction with solving challenging real-world and abstract problems. To gain proficiency and confidence in problem-solving, students must experience the reward of arriving at solutions through their own efforts (Honig, 1985). Workplace skills are defined to be those skills which lie between specific technical skills and specific factual knowledge. These skills include basic communication, basic math skills, organizations skills, and problem-solving skills (Hollenbeck, 1994). As discovered by the Education for Employment Outcomes Task Force in their 1994 study on workplace skills needed for success in the Kalamazoo and St. Joseph, Michigan labor market, problem-solving skills were needed in all three areas assessed. These included academic skills, personal management skills, and teamwork skills (Hollenbeck, 1994).

Methods of teaching problem-solving vary from hands-on instruction involving student discovery to instructor guided question, answer, and reflect sessions. However, the procedures used in problem-solving may be divided into components to guide

instruction. Four basic steps in problem-solving include: formulating problems, analyzing problems and selecting strategies, finding solutions, and verifying and interpreting solutions (Honig, 1985).

Applied mathematics skills needed in the workplace include a mathematics vocabulary that contains geometric terms such as area and volume, and their respective units of measure (Hollenbeck, 1994). Spatial reasoning ability appears to be a necessity for everyday functioning, but its description and assessment are complex tasks (Davey & Pegg, 1991). Measurement, which includes use of basic math skills involving fractions and decimals, is used in a variety of workplace situations. All of these skills are necessary for student success in geometry problem-solving.

The use of computer technology in teaching problem-solving skills is evolving rapidly. Interaction between students from around the globe provides a forum for discourse and analysis of problems relevant to students and societies. The National Geographic Society's KidNet has spawned many on-line, E-mail projects that present opportunities for groups to exchange and analyze data (Kelly, 1994). These students from various sites collect, exchange, aggregate, and analyze data as individual groups and as a whole. This process meets the criteria specified earlier in the definition of problem-solving. The POW, and the Archives accessible on the Internet from the MATH FORUM, at Swarthmore College, are two geometry problem-solving resources which were used in this study. In addition, the amount of time students communicated by using Internet E-mail was monitored to determine its effect on problem-solving achievement.

Assessing students' beliefs about doing mathematics is valuable for two reasons. First, students are in the process of formulating the belief structures that will influence the attitudes about school mathematics they hold as adults, whether as parents, teachers, or citizens. Such attitudes could have a powerful influence on the future direction of school mathematics. Second, listening to students' views about doing mathematics can give us important information now about how well the vision of the National Council of Teachers of Mathematics Standards is being realized (Wilson, 1995).

Lack of preparation in mathematics has severely limited career options for females. Researchers have suggested that females do not see math as important to their lives and that math is not an important part of their self definition. However, if female children are exposed to varied job or career possibilities and are provided with adequate instruction in mathematics, a wider variety of career options should become possible for females (Bernstein, 1992). Students who do well in school feel better about themselves: and in turn, they feel more capable. For most female students, this connection has a negative twist and a cycle of loss is put into motion. As girls feel less good about themselves, their academic performance declines, and this poor performance further erodes their confidence. This pattern is particularly powerful in Math and science classes (Sadker Et al., 1993). To prevent the disenfranchisement of girls from technology and related careers, technology must be changed to meet girls' needs (Fiore, 1999).

### Statement of the Problem

Do high school students' use of Swarthmore College's Math Forum Problem of the Week and the Math Forum Archives and communication via E-mail have an effect on their problem-solving achievement and their attitudes toward mathematics?

### Need for the Study

1. Due to the importance of developing problem-solving skills needed for success in higher education, many occupations, and numerous real-life situations, it would be beneficial to find additional problem-solving learning resources other than those commonly available to high school teachers.
2. If the amount of time that students are using Internet resources has an effect on problem-solving achievement, this knowledge will be helpful in the design of future programs.
3. If gender has an effect on problem-solving achievement for students who use problem-solving learning resources via the Internet, it will be important to know this so that programs which are not gender biased can be implemented.
4. If gender has an effect on the attitudes of students who use problem-solving learning resources via the Internet, it will be important to know this so that programs which are not gender biased can be implemented.
5. If high school student use of Internet-based problem-solving learning resources via the Internet derived has an effect on student attitudes toward mathematics, it will be beneficial to know this to help design future resources.

### Definitions of Terms

For the purpose of this research study, the following terms are defined:

1. Problem Solving - George Polya's definition in his book How To Solve It, written in 1945, states that problem-solving is a four-phase description which involves understanding, planning, carrying out the plan, and looking back. (Becker & Miwa, 1992). Another description includes the steps: formulating problems, analyzing problems and selecting strategies, finding solutions, and verifying and interpreting solutions (Honig, 1994).
2. Internet - The Internet is a network of networks that serves as an information conduit for the transfer of messages and files (Becker & Miwa, 1992). Historically, the Internet is the network of networks throughout the world that provides the link for electronic communication by using the IP (Internet Protocol) suite of protocols (Willson, 1993). The Internet is a three-level hierarchy composed of backbone networks (e.g., NSFNET, MILNET), mid-level networks, and stub networks. The Internet is a multiprotocol internet (Sandy, 1994).
4. Internet Learning Resource - Math resources available on the Internet include Centers for Research, Math Education Articles, Courses and Organizations, Graphics, Movies and Visualizations, Lesson Plans, Problems and Puzzles, Journals, Newsletters and Books, Reference Materials, Software Archives, and Reviews of Products and Developers (Math Forum, 1999).
5. E-mail - This is short for Electronic mail, which is a system that allows people to send and receive messages with their computers. The system might be a large network

(such as the Internet), or a bulletin board system, (such as CompuServe), or a company's own office network.

6. Math Forum - The Math Forum is a National Science Foundation Project located at Swarthmore College, in Pennsylvania. Opportunities available through the Math Forum include Internet workshops for teachers, school networking support, web-based lessons and classroom materials, Ask Dr. Math, and the Problem of the Week with Archives (answers to all POW's for the past four years).

7. Math Forum Problem of the Week - The Problem of the Week (POW) is a practical application geometry problem provided by the Math Forum at Swarthmore College in Pennsylvania each week during the school year via the Internet. Students are allowed to submit solutions to the POW electronically, and the names and E-mail addresses of students who submit correct solutions are then posted on the Math Forum's Internet web site.

8. Students in the experimental group - The experimental group will (a) receive the POW for ten weeks, (b) receive access to solutions to the previous four years' POW's (the Archives), (c) receive access to communication with others to help facilitate the solution of the POW via Internet E-mail, and (d) receive ten weeks of classroom geometry instruction.

9. Students in the control group will (a) receive the POW for ten weeks, (b) not receive access to solutions to the previous four years' POW's (the Archives), (c) not receive access to communication with others via the Internet, and (d) receive ten weeks of classroom geometry instruction.

10. Entering Geometry Student Test (EGST) - This is a prior geometry knowledge test developed by the Cognitive Development and Achievement in Secondary Schools Geometry team headed by Dr. Zalman Usiskin at the University of Chicago in the early 1980's. A copy of this test can be seen in Appendix B.

11. University of Minnesota's Mathematics Attitude Inventory (MAI) - This instrument was developed for research purposes by the Minnesota Research and Evaluation Project in 1972, by Wayne W. Welch, and was designed to measure the group attitudes of secondary students towards mathematics. A copy of the instrument can be seen in Appendix A.

12. McBride Geometry Problem-Solving Test (PST) - This is a test developed by Beth McBride in her doctoral dissertation titled A Convergent and Discriminant Validity Study of Several Instruments Used to Measure and Predict Performance in Formal Geometry. This is a five-question test designed to assess the problem-solving achievement of high school geometry students. Included with the test is a scoring rubric to assure consistent evaluation. A copy of the McBride Problem Solving Test and the rubric used to score it can be seen in Appendix G.

#### Questions to be Answered

1. Is there a difference in the basic geometry knowledge of participants in the experimental and control groups before treatment, as measured by the Entering Geometry Student Test (EGST)?

2. Is gender related to the basic geometry knowledge of high school geometry students before treatment, as measured by the EGST?
3. Is there a difference in the attitudes of participants in the experimental group and the control group towards mathematics before treatment, as measured by the University of Minnesota's Mathematics Attitude Inventory (MAI)?
4. Is there a difference in the attitudes of participants in the experimental group and the control group towards mathematics after treatment, as measured by the MAI?
5. Do the attitudes towards mathematics of participants in the experimental group before treatment differ from their attitudes toward mathematics after ten weeks of treatment, as measured by the MAI?
6. Do the attitudes towards mathematics of participants in the control group before treatment differ from their attitudes toward mathematics after ten weeks of treatment, as measured by the MAI?
7. Is gender related to the attitudes toward mathematics of participants in the experimental group before treatment, as measured by the MAI?
8. Is gender related to the attitudes toward mathematics of participants in the experimental group after treatment, as measured by the MAI?
9. Is gender related to the attitudes toward mathematics of participants in the control group before treatment, as measured by the MAI?
10. Is gender related to the attitudes toward mathematics of participants in the control group after treatment.

11. Is there a difference in the ten-week average of POW scores (WK10AV) achieved by participants in the experimental group and the control group after treatment?
12. Is gender related to the ten-week average of POW scores (WK10AV) after treatment, by participants in the study?
13. Does the amount of time participants in the experimental group spent using the Math Forum Archives have an effect on their WK10AV?
14. Does the amount of time participants in the experimental group spent using the Math Forum Archives have an effect on their problem-solving achievement as measured by the McBride Problem-Solving Test (PST)?
15. Does the amount of time participants in the experimental group spent communicating with others on the solution of the POW via E-mail have an effect on their WK10AV?
16. Does the amount of time participants in the experimental group spend communicating with others on the solution of the POW via E-mail have an effect on their problem-solving achievement as measured by the PST?
17. Is there a difference in the problem-solving achievement of members of the experimental group and the control group after treatment, as measured by the PST?
18. Is gender related to the problem-solving achievement of participants after treatment, as measured by the PST?

## Review of the Literature

### Introduction

For the purposes of this study, the literature was reviewed with regard to (a) workplace and educational needs for problem-solving, (b) methods of teaching geometry problem-solving skills, (c) teaching problem-solving skills by using modern technology, (d) use of the Internet in teaching geometry problem-solving skills, (e) gender issues in achievement and attitudes toward mathematics, and (f) the history of the Math Forum Problem of the Week.

### Workplace and Educational Needs for Problem-Solving

Employment environments rarely model what is seen in a traditional classroom. As opposed to the typical classroom filled with 30 students and one teacher at the front of the classroom lecturing, most work environments require the interaction of the employees to accomplish a goal (Corcoran, 1993). Employees must work and communicate together. They must also be flexible when situations occur that are not the norm. The use of computer networks and collaboration between users appears to be more compatible to the needs and training of the work force of the future than the traditional methods still used in many classrooms around the world (Reinhardt, 1995).

Problem-solving skills are useful in all occupations that involve reading technical material or tackling difficult problems. With the growth of technology, occupations such as X-Ray technicians, TV repairmen, registered nurses, computer programmers, automotive

repair specialists, and accountants are called upon to complete and coordinate advanced areas of knowledge (Whimbey & Lochhead, 1991).

Computer-based education and training in the future must link the needs of industry with the goals of public education. Explosive growth in CD-ROM drives, multimedia, and collaborative software environments are restructuring the way classes are being taught from elementary schools through advanced college degrees. Training for industry requires students to utilize a different set of skills than those previously taught in our nations schools. Teachers change from omniscient leaders to tour guides for the infosphere (Reinhardt, 1995).

Problem-solving should be the central focus of the mathematics curriculum. As such, it is a primary goal of all mathematics instruction and an integral part of all mathematical activity. Problem-solving is not a distinct topic but a process that should permeate the entire program and provide the context in which concepts and skills can be learned. The National Council of Teachers of Mathematics (NCTM) standards emphasize a comprehensive and rich approach to problem-solving in a classroom climate that encourages and supports problem-solving efforts. Ideally, students should share their thinking and approaches with other students and with teachers, and they should learn several ways of representing problems and strategies for solving them. In addition, they should learn to value the process of solving problems as much as they value the solutions. Students should have many experiences in creating problems from real-world activities, from organized data, and from equations (NCTM, 1989).

The report from the National Alliance of Business, addresses the explosion of technology in the workplace and states that skill level requirements are being ratcheted up by employers. Inventory, sales, marketing, expense analysis, communication and correspondence are all being done faster, better, cheaper, and with greater efficiency in the workplace today, through the use of technology. Preparing students and employees to effectively use technology is a challenge facing today's educators and trainers. At the same time, technology also holds promise to help educate students and train workers faster, better, and cheaper. Richard C. Notebaert, Chairman and CEO of Ameritech, recently stated, "Our challenge is to address the needs of entry-level workers as well as mid-level hires, and to make the wise use of technology the catalyst for achieving our new environment". The use of computers on the job has nearly doubled over the past nine years, and the use of technology has produced a 30% reduction in training time and a 30%-40% reduction in training cost (National Alliance of Business, 1997).

#### Methods of Teaching Geometry and Problem-Solving Skills

Ethridge addresses the issue of changes in the needs for problem-solving skills. He states that changes in methods of teaching problem-solving have become necessary due to the changing knowledge, skills, and attitudes needed to function effectively in an industrial age. In the 1980's and early 1990's we have witnessed a dramatic shift in the needs of business and industry and of society in general. While students continue to need mastery of such enabling skills as reading, writing, and computing, they must also master the new

basics which include creative thinking/problem-solving, interpersonal skills, negotiation and teamwork (Ethridge, 1992).

Traditional methods of teaching mathematics included tightly sequenced content through direct instruction, hands-on learning activities, in-class and out-of-class assignments, in-class lecture, and discussion. Changes today are characterized by cognitively guided ideals with technology used as a vital part in creating an information-rich classroom. As individuals begin to understand the complex nature of learning and the advantages technology bring to the classroom, the shortcomings of traditional learning and instruction become evident (Nicaise & Barnes, 1996).

According to the National Council of Teachers of Mathematics (NCTM) Principles and Standards, mathematics instructional programs should include attention to geometry and spatial sense so that all students (a) analyze characteristics and properties of two- and three-dimensional geometric objects, (b) select and use different representational systems, including coordinate geometry and graph theory, (c) recognize the usefulness of transformations and symmetry in analyzing mathematical situations, and (d) use visualization and spatial reasoning to solve problems both within and outside of mathematics (NCTM, 1998)

The NCTM Principles and Standards recommend that mathematical instructional programs focus on solving problems as part of understanding mathematics so that all students (a) build new mathematical knowledge through their work with problems, (b) develop a disposition to formulate, represent, abstract, and generalize in situations within and outside mathematics, (c) apply a wide variety of strategies to solve problems and

adapt the strategies to new situations, and (d) monitor and reflect on their mathematical thinking in solving problems (NCTM, 1998).

### Teaching Problem Solving Skills by Using Modern Technology

The world of computer technology in classroom education has evolved into a realm of opportunity which could hardly have been considered possible only 20 years ago. The innovative uses of computer technology, its contributions to teaching and learning, and some of the limitations and/or drawbacks are included in this section of the review of the literature.

Seymour Papert, professor of learning research at MIT Media Laboratory, believes that a future device called a Knowledge Machine would combine highly advanced storage and access technologies and would enable very young students to know what others know, and to learn by searching a whole universe of knowledge. He also proposes that the primacy of reading books will unravel, even though written language is not likely to be abandoned (Fisher, 1994). According to U.S. Secretary of Education Richard Riley, the 1993 National Center for Educational Statistics annual report paints a picture of a society in which the vast majority of Americans are unprepared for a future in which work will require increasingly sophisticated skills. In addition, David Britt, president of Children's Television Workshop said: "The coming levels of interactive technology hold the potential to create order-of-magnitude changes in the productivity of American education" (Fisher, 1994).

What are the returns on the investment in computer technology? Use of technology can boost retention rates, reduce boredom and misbehavior, and, in many cases, reduce costs. The SPA's Report on the Effectiveness of Technology in Schools, 1990-1994, a summary of 133 studies, found that educational technology clearly boosted student achievement, improved student attitudes and self-concept, and enhanced the quality of teacher-student relationships (Reinhardt, 1995). Another added advantage of computer technology is that computers are amazingly patient teachers. Other key factors on successful implementation of computer technology is the use of programs which adapt to individual needs, hands-on learning, teamwork, and guided discovery. User-friendly programs which adapt to individualized needs are very cost effective, since students do not need to be assembled in one place at one time. Another advantage that appropriate computer software affords is the fact that students are allowed to analyze their own mistakes without fear of embarrassment (Reinhardt, 1995).

Service addresses changes in the methods of delivery of course content which have emerged due to the use of modern technology. Although a database search is often a major utilization of network technology, other information available on networks that proves to be very valuable to students is access to tutorials created by educators. Physics professor Laurence Marschall, of Gettysburg College in Pennsylvania, has provided tutorials on-line at no charge for all who have access to the Internet. More than 1000 people around the world obtained free copies of his tutorials during the first nine months they were available. The next step, which was to design computer-based course materials and instruction manuals, and make them available to anybody with a computer, modem,

and Internet access is also a reality today. Courses in Biology, Astronomy, and Computer-Assisted Graphics can also be accessed through the Internet, and the number of courses available over the Internet is expected to increase rapidly in the next few years. Textbook publishing companies are producing free computer software supplements to trim the size and costs of some of their texts and lab books. There is also the possibility that manuals could be distributed to students over local and wide area networks (Service, 1994).

Reinhardt feels that one technological breakthrough used to improve problem solving skills is the use of multimedia. Multimedia encompasses a range of data types, including analog and digital video, two-dimensional and 3-D animation, audio, and hyperlinks. It also includes delivery media such as CD-ROM discs and drives, graphics display hardware (e.g., compression/decompression, acceleration, and coded cards), and sound cards. Specialized hardware devices such as digital signal processors (DSP) for speech and signal processing, are starting to appear in desktop systems and will play an increasing role in learning systems (Reinhardt, 1995). According to Quality Educational Data (QED), a research firm from Denver, Colorado, 25 percent of school software budgets in 1994 were allocated to multimedia titles. The combination of visual and auditory presentations boost retention rates to 50 percent according to Howard Wactlar, Vice Provost for Research Computing at Carnegie Mellon University. According to QED, The number of K-12 schools with CD-ROM drives has nearly tripled since 1992 (Reinhardt, 1995). Considering the positive results from technology use and learning reported by Reinhardt, further investigations in this area seem essential.

Reform efforts, such as those of the National Council of Teachers of Mathematics (NCTM), are designed to move the teaching of mathematics from a rote memorization and paper-and-pencil orientation to one of understanding, appreciation, and relevance using technological tools such as computers and graphing calculators. Technological tools such as laser discs, CD-ROMs, a variety of software, and on-line resources offer numerous opportunities to link theory to practice by providing realistic contexts for mathematics. (Bratina & Bosnick, 1997).

According to Rosenthal, impediments to the use of technology in teacher education programs include the lack of hardware and software necessary to incorporate technology into the teaching agenda. In many instances, education faculties have not been provided the training they need to use technology effectively. A majority of teacher education departments have not been able to invest in the technical support required to maintain a high-quality technology program. Finally, some higher education faculties have little understanding of the changes technology is bringing to K-12 classrooms, and have not adjusted their own teaching methodologies to reflect these changes. In the long run, technology will profoundly change the instructional process in the classroom, enhancing the ability to track students' progress, individualize instruction, do research, carry out experiments, and record and organize information. (Rosenthal, 1999).

Research and the best teaching practices consistently show that without effective staff development and continuous support, technology integration will never be satisfactorily achieved. Unless technology leaders can understand and meet human needs, the systemic integration of technology into education may not take place in the next

century. People have to work in an environment in which technology is integrated with the infrastructure. Potential users should not perceive technology as an "add-on."

Technology is found everywhere in the learning environment, and it must become as transparent as pens, pencils and books are in today's classroom (Bailey & Brownell, 1998).

### Use of Internet Resources in Teaching

In addition to searching databases, the use of E-mail is perhaps the most frequently used feature of the Internet (Kelly, 1994). Some examples include a project in which students across America tracked the progress of four men biking 10,000 miles in Africa, via reports filed by the riders on an international teacher's network. Students were able to inquire about the geography of the areas the bikers traveled through, and even compare scientific experiments performed locally themselves with the results obtained on similar experiments performed by the travelers and other students from around the world. By tapping into the network, many students were able to communicate with other students in a way never experienced by their parents (Corcoran, 1993). The Vermont EdNet is a state-funded network for teachers and students. This network provides an educational resource that allows responses to inquiries from educators located in all areas of the state (Corcoran, 1993). Last year, The Institute for Research in Learning, a nonprofit group in Palo Alto, California, founded by Xerox, helped middle-school math teachers work with scientists from Sandia Labs to develop a curriculum based on designing a mock research station in Antarctica. The object of the program was to attract students who traditionally

drop out and make them feel confident that they could see the world mathematically (Corcoran, 1993)

A program sponsored by the National Geographic Kids Network involved the participation of more than 10,000 elementary school classes by allowing the students to conduct experiments and pool their results with kids doing similar work in other parts of the world. Some 35,000 kids plugged into the Learning Network, a 23 nation Social Studies and Literature program run by AT&T (Corcoran, 1993).

Numerous descriptions of the uses of computer technology have been presented, and the impact of their adoption upon education has been offered. The final portion of this review is devoted to the logistics involved to enable widespread adoption of computer technology in the classroom and what specific problems have been encountered as school districts have tried to implement this technology. The matter of financing this technology is also addressed.

A common theme found among users was being overwhelmed by the amount of information available. Much of the information found was not useful to the end-user. Also, the amount of time needed to access desired material was frustrating for students and teachers. Often, this time interpolated into higher expenses for network usage (Danin, 1993). The lack of access to specialists to help with problems which were encountered also led to confusion and frustration. Access to specific locations on the Internet were often denied, and lack of graphics interfaces also presented problems for classroom use. Phone line access and expense also limited use by some participants in rural areas (Rogan, 1995).

Where does the money for school computers come from? To get their students on-line, many teachers dig into their own pockets. Other sources of financing come from the National Science Foundation, nonprofit organizations, and businesses. A national trend which includes employing the help of community volunteers to route wiring, and using student computerphiles for training students and teachers has eased the burden of cost in many school districts. The Software Publishers Association (SPA) of Washington D.C., reports that approximately \$2.4 billion was spent in 1994, on educational technology (Reinhardt, 1995).

By using Internet-based resources to support math instruction, it is possible to find the desired relevance, real-world content, and opportunities for problem-solving and communication essential to adult mathematical literacy. Using E-mail, instructors from Oregon have been involved in math keypal (electronic penpal) problem exchanges around the state and nation. Many government and research organizations make data available via the Internet including charts, graphs and tables which can be used for data analysis, statistics and probability (Cowles, 1998).

#### Gender Issues in Achievement and Attitudes toward Mathematics

Well into the twentieth century, boys and girls were assigned to sex-segregated classes and prepared for different roles in life (Sadker, Et. al.). Even today, classrooms at all levels are characterized by a general environment of inequity, and bias in classroom interaction inhibits student achievement. From grade school to graduate school to the world of work, males and females are experiencing different educational environments

even in the same classroom. This gender bias affects self-esteem, educational attainment, career choice and income (Sadker & Sadker, 1986).

For over twenty years, educators in many parts of the world have been concerned about gender inequities in mathematics education. This concern has led to extensive research, seeking to document any gender differences in mathematics learning, find explanations, and develop strategies for change. World-wide interest in the issue of gender and mathematics education has been high. The International Commission on Mathematical Instruction sponsored a conference on the topic, held in Sweden in 1993, and several international journals have produced special issues devoted to research in this area. (Atweh, 1996). Results of national studies suggest that for girls, the middle grades can be a time of significant decline in self-esteem and academic achievement (AAUW, 1991). Analysis of the Harvard Project on Women's Psychology and Girls' Development supports the finding that many girls seem to think well of themselves in the primary grades but suffer a severe decline in self-confidence and acceptance of body image by the age of 12 (Orenstein, 1994). In her University of Bridgeport dissertation research on gender and self-concept conducted using the Mathematics Self-Concept Scale, Lammia Agoora found that female students scored lower than male students (Agoora, 1997). ✓

Reasons for the decline of females in self-esteem and the accompanying decline in academic achievement are not clearly defined by research, but it is likely that multiple factors are involved (Rothenberg, 1995). Peterson, Burton, and Baker reported finding no significant difference between female and male geometry students in their self-concept as geometry students, although differences according to success and teacher were found

(Peterson, Burton, Baker, 1983). Questions about sex differences are important, because they inform researchers, curriculum designers, and classroom teachers of ways in which the potential of all students can be more equitably and effectively addressed (Peterson, Burton, Baker, 1983). In reference to self-concept and success in mathematics, sex differences in mathematics achievement can be related to the affective climate of the school. In schools in which mathematics was perceived as a male domain, females differed from males in that they did not expect to succeed in mathematics, did not find math useful, and had lower scores. These differences were not found in schools in which the school climate was not gender dominated (Sherman and Fennema, 1977). Students who do well in school feel better about themselves; and in turn, feel more capable. For most female students, this connection has a negative twist, and a cycle of loss is put into motion. As girls feel less good about themselves, their academic performance declines, and this poor performance further erodes their confidence. This pattern is particularly powerful in math and science classes (Sadker, Et al.).

The 1990 British Columbia Mathematics Assessment Technical Report documented that boys rated the importance of area, perimeter, volume, geometry, and trigonometry considerably higher than females. On the other hand, girls rated fractions, decimals, and percents more highly. Girls enjoyed working with fractions, decimals, and percents, equations, expressions and exponents more than boys. The only topic on which boys expressed an enjoyment level significantly higher than girls was on geometry (Robitaille, 1990).

Due to the need of mathematics in many careers, choice of high school math classes can have an effect on future career choices. Females have been found to be less likely to select courses in high school mathematics. Math anxiety has been suggested as an explanation for the lack of interest on the part of females in math and science intensive career options (Singer and Stake, 1986). Fear of math and working with mathematical concepts may be one of the factors which prevent women from choosing employment training programs which could lead to higher paying positions. Many technological oriented and managerial positions are not available to women because of their lack of ability to work with mathematical concepts. By increasing their proficiency in the area of mathematics, additional career opportunities will become available to them. (Bernstein, 1992).

Friedman addresses the effects of gender on spatial relations and the relationship of success in spatial skills to success in mathematics. It has been thought in the past that there was a correlation between spatial skill and success in mathematical tasks. To gain proficiency in geometry, students must recognize and manipulate figures in space, so spatial skills are very important. If there were gender differences in spatial skills, this could have an effect on success of students in high school geometry classes. Correlational evidence does not indicate that spatial skill plays a special role in mathematical achievement as mathematics is taught and tested today. According to Friedman, gender patterns sometimes vary. Females' correlations do not differ according to the cognitive level of the mathematics task as often as do those of males. Females have higher verbal-mathematics than space-mathematics correlations in more categories than do males.

Correlational evidence does not support the hypothesis that spatial skill underlies gender differences in mathematics (Friedman, 1992).

Age differences have been shown to affect the math anxiety of both males and females. Although not statistically different at age twelve, male students express slightly more math anxiety than female students. At age 13, the two groups exhibited similar feelings of anxiety, and by the age of fourteen, female students were more anxious about math than male students. The feelings of math anxiety expressed by females were consistently higher than those of male students until age nineteen (Bernstein, 1992).

Bernstein found that race was significantly related to feelings of math anxiety for both males and females. Males in the African American, Hispanic, Asian and Native American groups exhibited high levels of math anxiety. The highest levels of math anxiety for females were found in African American and Hispanic groups. Among Asian and Native American groups, males were found to be higher in math anxiety than were female participants. Male and female African American and Hispanic groups were similar in their feelings of math anxiety. Among Caucasians, females were found to be higher in feelings of math anxiety than males (Bernstein, 1992).

Frykholm addresses the effects of gender on student success in geometry. In the van Hiele theory of geometry learning and development, every geometry student progresses through a series of cognitive levels in their quest to master geometry. If there were differences in the progression of males and females through this series of cognitive levels, it would indicate that a change should be made in the way geometry is taught, so that both sexes would progress similarly. Gender had no significant relationship with van

Hiele levels. Gender had little or nothing to do with a student's potential in geometry. The knowledge that gender differences are not significant predictors of geometry achievement dispels the common myth that female students are not as capable of achieving high standards of excellence in math as their male peers. The fact that this has been documented statistically is meaningful information that should be discussed with both teachers and students (Frykholm, 1994).

A gender gap in computer use and interest seems to begin at the middle school level and widens as the girls become older. Gender differences are more evident in advanced than introductory classes. Far more boys than girls have strikingly positive attitudes toward computers, finding them more enjoyable, important, and friendly (Lavin & Gordon, 1989). To prevent disenfranchisement of girls from technology and related careers, technology must be changed to meet girls' needs. Presently, girls have fewer educational environments and role models that awaken their interest in technology. Middle school girls seem to enjoy technology education and are confident in their abilities, but most of them do not continue with this education in high school. Girls still tend to be less confident in their abilities to use computers, and both sexes still perceive computers predominantly as the domain of males. Obviously, computers are gender neutral, yet, in their use, they sometimes reinforce gender differences (Fiore, 1999). In his study of the relationship of computer anxiety to mathematics, Yuko Otomo, of Columbia University Teacher's College, found that the correlation between computer anxiety and mathematics was significant and positive and that females had higher mathematics anxiety than males (Otomo, 1998).

### History of the Math Forum Problem of the Week

The Math Forum at Swarthmore College (<http://forum.swarthmore.edu>) is an outgrowth of the Geometry Forum project started in 1992. This project established an electronic community where all interested in geometry could turn to find colleagues and resources on the Internet. By necessity, they found themselves working extensively with teachers and students, from kindergarten to college, and ventured into other areas of mathematics. Activities now include Internet workshops for teachers, summaries of math education research published in newsgroups, school networking support, Ask Dr. Math, the Elementary Problem of the Week, project Archives and Internet resources indexes, web-based lessons and classroom materials and the Math Forum Problem of the Week (Math Forum, 1999).

The Math Forum is a project sponsored by the National Science Foundation and is designed to investigate the viability of a virtual math education. The technology center supports the development of an exciting, innovative community of teachers and students, creators and appliers of mathematics, the education community, and all others with an interest in mathematics (Math Forum, 1999).

The POW is presented on the Math Forum website on a weekly basis during the school year. Also, in the past five years problems have sometimes been available to students during the summer months. Annie Fetter is the coordinator of the POW. Students from all over the world submit their solutions each week electronically. Annie assesses the correctness of all solutions, and provides examples of correct solutions and the names and school addresses of the successful students on the Math Forum website.

## CHAPTER 2

## DESIGN AND METHODOLOGY OF THE STUDY

Introduction

According to George Polya, in his book How to Solve It, written in 1945, one of the most important tasks of the teacher is to help his students. The student should acquire as much experience of independent work as possible. The teacher should help, but not too much and not too little, so that students have a *reasonable share of the work*. If the student is not able to do much work, the teacher should leave him at least some illusion of independent work. The teacher should help the student discreetly, unobtrusively. The best is, however, to help the student *naturally*. The teacher should put himself in the student's place, try to understand what is going on in the student's mind, and ask a question or indicate a step that could have occurred to the student himself. According to Polya, the constructivist paradigm should be used (Polya, 1945).

To efficiently and economically utilize technology to improve the delivery and impact of education upon students who will lead our nation in the future, it is necessary to conduct research to determine how this technology can yield the greatest return. Projects and activities which show Value-Added to traditional methods of geometry problem-solving teaching should continue to be utilized, where activities which prove not to be productive should be discarded. Only by legitimate professional research can the positive benefits of technology be properly utilized. The purpose of this research was to

investigate the use of suitable technology in education and encourage continued research in the future so that new learning resources which positively affect problem-solving achievement can become part of the regular high school geometry curriculum.

The theoretical framework of my research is based on the combination of two phenomena. The first premise of my research is that, in some unobtrusive way, the teacher should provide the students with an avenue for learning that includes non-traditional opportunities for the development of problem-solving skills. The second is that developing student confidence in their ability regarding problem-solving skills is necessary for many technical occupations today and exposure to problem-solving learning resources may help improve student attitudes and self-confidence toward mathematics. Included in the research is the opportunity for students to communicate with others via Internet E-mail in the solution of weekly Math Forum Problem of the Week (POW). Another goal is to allow students to progress naturally and expand from their own knowledge database.

#### Description of Population and Sampling Procedures

The population in this study consisted of Montana high school geometry students. Three teachers were chosen to participate in the study. One teaches geometry at Columbus High School, Columbus, Montana, and two teach geometry at Skyview High School in Billings, Montana. One of the criteria necessary for participation in the study was that teachers taught two sections of high school geometry every week for the entire semester. Another criteria was that the participating schools were connected to the Internet, and that computers were available to the participating students during their class

periods. Through a random selection process, each teacher designated one of their geometry classes as the experimental group and the other as the control group. The experimental group for each participating teacher received access to the Internet during the twenty minutes chosen each week for student solution of the POW. The control group for each participating teacher did not receive Internet access during the twenty minutes chosen each week for student solution of the POW. There were 53 students in the experimental group and 51 students in the control group who participated in the study

Schools in the sample were selected so that there were at least two geometry classes taught by the same teacher so that both the experimental group and the control group were taught by the same teacher. This eliminated the variability which might occur if different teachers taught the experimental and control groups respectively.

In this research study, the sample was a Cluster or Multi-Stage sample, since specific classrooms of students were be selected. Random selection of sample classrooms in Montana was not possible due to the fact that not all schools in Montana have Internet access.

#### Description of Treatments

Both the experimental group and control group received the POW each week for ten weeks during the spring semester of 1998. The experimental group for each participating teacher had access to the Math Forum Archives and the opportunity to communicate with others via Internet E-mail during their weekly quest to solve the POW. The control group for each participating teacher did not receive access to the Math Forum

Archives or the opportunity to communicate with others via Internet E-mail during their weekly quest to solve the POW.

From March 2, 1998, through March 6, 1998, instructions were given to participating teachers and students regarding (a) retrieval of the POW from the Internet, (b) accessing the Math Forum Archives with answers to previous years' POW's, (experimental group only), (c) communication with others via Internet E-mail to solve the POW (experimental group only), and (d) completion of Student Participation Questionnaires.

During the days of March 9-13, 1998, each of the three participating teachers administered a set of two tests to all participating members of their two high school geometry classes. The first test was a Mathematics Attitude Inventory (MAI), which took 20 minutes to administer, and the second was an Entering Geometry Student Test (EGST), which consisted of 20 multiple choice questions, and took 20 minutes to complete. These tests were delivered to participating teachers by March 3, 1998, and were returned by the teachers to the researcher upon their completion by participating students. The researcher determined the results of both tests, and protection of confidentiality was assured.

Each of the three participating teachers received their first POW on March 16, 1998, via the Internet, and continued to receive a new POW for each week of the ten-week period of the study. Each week, participating teachers downloaded the current POW from the Math Forum at Swarthmore College, photocopied them and distributed the POW to students in both the experimental and control classes. The students were allowed

twenty minutes during their geometry class period each week to work on the POW. However, the experimental group taught by each of the three participating teacher had access to Internet interface, which included (a) answers to previous POW's (the Archives) and (b) communication with others via Internet E-mail regarding the solution of the current week's POW. The control group received the POW, but not Internet access each week during the time designated for their solution of the POW. Each participating teacher was expected to integrate the POW into their class schedule and investigate the answer for a period of 15-30 minutes each week.

Following their students' completion of ten weeks of solving the POW, each of the three participating teachers administered a set of two tests to all members of their participating high school geometry classes. The first test was the University of Minnesota's Mathematics Attitude Inventory (MAI), which took twenty minutes to complete and measured group attitudes toward mathematics and the second test was the McBride Problem-Solving Test (PST), which took twenty-five minutes to complete and measured geometry problem-solving achievement. The tests were collected by the participating teachers and picked up after their completion by the researcher. All tests were assessed by the researcher and protection of confidentiality was assured.

### Methods of Data Collection

#### Introduction

Choice of measuring instruments and methods of their scoring were critical components in this research, due to the complex nature of assessing problem-solving

achievement and student attitudes towards mathematics. Three tests were needed for the study. One test was used to determine the basic geometry knowledge of the participating high school geometry students. A second test was needed to determine the students' attitudes toward mathematics in six different categories, before and after treatment. The third test was needed to determine the problem-solving achievement of participating students after treatment.

### Testing Instruments

Selected for its time-proven reliability and validity, the Entering Geometry Student Test (EGST) was used in the beginning of the research to determine prior basic geometry knowledge of participating students. This test was developed by the Cognitive Development and Achievement in Secondary School Geometry team at the University of Chicago. A confirmation of the reliability of the test was that it had a Chronbach alpha of .77. There were twenty questions on the test, and twenty minutes were allowed for completion of the test. Scoring was based on the number of problems answered correctly.

The Mathematics Attitude Inventory (MAI) from the University of Minnesota's Psychological Foundations of Education Department was used at the beginning and the end of the study to determine group attitudes toward math. The MAI consisted of 48 statements about the study of mathematics. Students read each statement and decided whether they strongly agreed, agreed, disagreed, or strongly disagreed with the statements. The test is highly respected, valid, and reliable, and its scoring was conducted in accordance with specified methods. The six categories measured by the MAI with their

corresponding Chronbach alpha reliability coefficients in parentheses included: (a) student perception of the mathematics teacher (.83), (b) anxiety toward mathematics (.86), (c) value of mathematics to society (.77), (d) self-concept in mathematics (.83), (e) enjoyment of mathematics (.85), and (f) motivation in mathematics (.76). Twenty minutes were allowed for completion of the test. Only 38 of the 48 items on the test were used in determining scores for the six categories, and no item was used in more than one category. Scores for each category were determined by using a formula provided by the test developers at the Minnesota Research and Evaluation Center at the University of Minnesota. Each category was analyzed regarding treatment and gender. A higher score indicated a more positive attitude in each specific category.

The McBride Geometry Problem Solving Test (PST) was selected to determine problem-solving achievement by students in the experimental group and the control group after treatment. The test and analytical scoring rubric were developed by Bethe McBride in her Doctoral Dissertation, A Convergent and Discriminant Validity Study of Several Instruments used to Measure and Predict Performance in Formal Geometry, 1995. The PST consisted of five geometry problems and the time allowed for completion was twenty-five minutes. The PST was a very internally consistent test. It had a very high Chronbach alpha ( $\alpha=.97$ ). The Chronbach alpha can be considered a measure of reliability and indicates a highly reliable test. The PST had high communalities ranging over .63, which indicates a high level of internal consistency for the PST as well as good construct validity. The scoring rubric designed for test assessment consisted of evaluations of student proficiency in the use of theorems, interpretation of diagram and markings,

recognition of terminology, knowledge of definitions, and development of problem-solving strategies (McBride, 1995).

### Student Participation Questionnaire

Participating students were required to complete a Student Participation Questionnaire each week during the study. Included on the weekly questionnaire was the student's solution to the current week's POW, the amount of time spent using the Math Forum Archives and communicating via Internet E-mail in the solution of the POW (for the experimental group only), and information related to the importance students placed on the resources available to them during their solution of the week's POW. The Student Participation Questionnaires for the experimental and the control groups can be seen in Appendix C.

## Research Design

### Teacher and Student Research Participation Training

The initial phase of this research was for the researcher to conduct training sessions for both the teacher and student participants. The researcher personally met with all three participating teachers and their six respective participating classes for the following training sessions:

Teachers:

- (1) How to obtain and distribute the POW each week,
- (2) How to access Archive data and communicate via E-mail regarding the POW  
(Number two is for the experimental group only)
- (3) How to complete Student Participation Questionnaires
- (4) Distribution, administration and collection of testing instruments
- (5) Distribution and collection of Student/Parent Research Permission Forms  
( A copy of the Student/Parent Permission Forms can be seen in Appendix H)

Students: (With Teacher Present)

- (1) How to complete Student Participation Questionnaires for the ten-weeks
- (2) Classroom participation regarding solutions to the POW
- (3) Incentives for students to participate in the research

Completion of Initial Testing Instruments

Upon receipt of all signed Student/Parent Research Permission Consent Forms, the next phase of the research began. During the week before distribution of the first POW on March 16, 1998, from the Math Forum, participating teachers distributed the Entering Student Geometry Test (EGST) during the regular classroom period to their respective experimental and control groups for completion and return. The amount of time allowed to complete this test was 20 minutes. Also during this week, teachers distributed the University of Minnesota's Mathematics Attitude Inventory (MAI) for student completion and return during the regular classroom period. Time allowed to complete this test was 20

minutes. The participating teachers then returned all of these tests and the corresponding student answers to the researcher, for assessment and future analysis.

#### POW and Student Participation Questionnaire completion

During the ten-week period of the study, as students from all six classes attempted to solve the POW, they were required to complete a Student Participation Questionnaire during the twenty minutes allowed for solution of the current week's POW. Included on the weekly questionnaire was the student's solution to the current week's POW, the amount of time spent using the Math Forum Archives and communicating via Internet E-mail in the solution of the POW (for the experimental group only), and information related to the importance students placed on the resources available to them during their solution of the week's POW. Each week the participating teachers assessed each student's POW solution with a scoring rubric provided by the researcher. This rubric was provided to the participating teachers weekly in either written form or electronically by E-mail. The POW solutions for each student were given an integral value of zero through three by their teachers each week. The POW scoring rubric was used to assure consistent scoring by each of the participating teachers. The completed Student Participation Questionnaires were collected by the researcher to be used in the statistical analysis of the study.

### Incorporation of the Internet for E-mail Communication and use of the Math Forum

#### Archives by participants in the Experimental group.

During the ten weeks that students in the experimental group received and attempted to solve the POW, they had access through the Internet to the following options:

- (1) Access to solutions of the previous four year's POW's (the Archives)
- (2) Access to Internet E-mail for communication with others to facilitate the solution of the current POW.

### Derivation of the ten POW's and their Correlation to Concepts on the PST

The ten problems which were used during the ten weeks of problem-solving data acquisition were composed jointly by the researcher and Annie Fetter of Swarthmore College's Math Forum. For additional information on the vital role played by members of Swarthmore College's Math Forum, see Appendix D. The problems used were selected to contain concepts necessary for the specific mathematical problem-solving skills needed for success on the McBride Geometry Problem Solving Test (PST). Copies of all ten Problems of the Week and the rubrics used to score them can be seen in Appendix E. A copy of The PST was administered at the end of the students' ten weeks of solving the POW. Concepts needed to solve weekly POW's included many of those seen in traditional high school geometry classes, including the Pythagorean Theorem, ratio and proportion and measures of angles of a triangle. In addition, several of the problems

represented geometry problem-solving questions which have attracted the interest of mathematics students for centuries. The following list shows the relationship between the concepts needed for the PST and those needed for solution of the POW's. Concepts needed for solution of Problem-Solving Test questions appear in the list of specifications below: A table of these specifications can be seen in Appendix F. (The numbers at the end of each concept represent the Problem of the Week in which that concept appeared)

#### PST Problem 1

- (A) Base Angles of an Isosceles Triangle are Congruent (POW's 2, 8)
- (B) Definition of Supplementary Angles (POW's 2, 10)
- (C) Solve an Algebraic Equation with One Unknown (POW's 2, 6, 10)
- (D) Sum of Measures of Interior Angles of a Triangle. (POW's 2, 8)

#### PST Problem 2

- (A) Coplanar lines perpendicular to the same line are parallel (POW's 7, 10)
- (B) Coplanar Parallel Lines cut off Proportional Sections on Multiple Transversals (POW's 4, 10)
- (C) Solution of Ratio and Proportion Problem (POW 4, 6, 8)

#### PST Problem 3

- (A) Base Angles of an Isosceles Triangle are Congruent (POW's 2, 8)
- (B) Sum of the Measures of the Interior Angles of a Triangle (POW's 2, 8)
- (C) Location of the Longest Side of a Triangle based on the Measure of the Interior Angles
- (D) How to Logically determine the largest side if more than one triangle is involved

#### PST Problem 4

- (A) Formulas for the areas of a circle and square (POW's 3, 5)
- (B) Concept of Conservation of Space (POW's 3, 5)

#### PST Problem 5

- (A) Could be solved by Hero's Formula (POW's 1, 9)

- (B) Definition of Area of a Triangle (POW's 1, 9)
- (C) Recognition of Right Triangle by Pythagorean Triple (POW's 1, 9)

### Completion of Final Testing Instruments

After a period of ten weeks in which participating students worked to solve the POW, final assessment on problem-solving achievement and student attitudes was conducted. During the week of May 25 - 29, 1998, the participating teachers administered to both the experimental and control groups the PST, originated and validated by Bethe McBride, which took 25 minutes to complete. These tests were graded by the researcher by using a scoring rubric provided by Bethe McBride, author of the PST. In addition, participating teachers administered and collected the MAI from both the experimental and the control groups.

### Grader Reliability for the McBride Problem-Solving Test

In the spring of 1997, the researcher administered the PST to two high school geometry classes at Bozeman High School, Bozeman, Montana, and assessed these tests using the rubric provided by Bethe McBride, the author of the PST. Two weeks later the researcher assessed all of these tests again and calculated a Pearson  $r$  to determine the inter-rater reliability coefficient. The Pearson  $r$  of .9527 confirmed the reliability and consistency of the researcher in assessing the McBride Problem-Solving Test.

## Analysis of Data

### Analysis of Variance and Covariance

Analysis of this research fell into five categories: (1) Analysis of variance of the basic geometry knowledge of the participating students before treatment, analyzed by method of treatment and gender, (2) Analysis of variance of the attitudes of students towards mathematics, analyzed by method of treatment and gender, before and after treatment, (3) Analysis of variance and covariance of the average mathematics achievement by students on ten Math Forum POW's (WK10AV) analyzed by method of treatment and gender, with the EGST as the covariate, (4) Analysis of covariance of the effect of using the Math Forum Archives and Internet E-mail communication on the WK10AV and achievement on the PST, with the time of Archive use as the covariate, and (5) Analysis of variance and covariance on achievement on the PST after ten weeks of treatment, analyzed by method of treatment and gender, with the EGST as the covariate. Criteria for the rejection of all null hypotheses was set at  $p \leq .05$ .

### Choice of Alpha Level

A Type I error is made if the null hypothesis is actually true (that is, the hypothesized relationship between the variables under study does not exist), but the null hypothesis is rejected on the basis of the significance test. A Type II error is made if the null hypothesis is actually false but, on the basis of the significance test, the null hypothesis is not rejected. The probability of making a Type I error, that is, rejecting a true null hypothesis, can be decreased merely by lowering the level of significance. Unfortunately,

as the probability of making a Type I error decreases, the probability of making a Type II error increases (Popham, Sirotnik, 1992). Common probability levels are .01, .05, and .10. For this study, the researcher chose the .05 probability level, because the .10 level would have increased the probability of a Type I error, yet the selection of the .01 level would have made it increasingly more difficult to reject certain null hypotheses that should be detected.

#### Statistical Hypotheses

The experimental group will receive:

- 1) the Problem of the Week (POW) for ten weeks
- 2) access to solutions to the previous four years' POW's (Archives)
- 3) access to communication with others via Internet E-mail during the twenty minutes allowed for solution of the POW each week
- 4) ten weeks of classroom geometry instruction

The control group will :

- 1) receive the Problem of the Week (POW) for ten weeks
- 2) not receive access to solutions to the previous four years' POW's
- 3) not receive access to communication with others via Internet E-mail during the twenty minutes allowed for solution of the POW each week
- 4) receive ten weeks of classroom geometry instruction

### Hypothesis 1

There was no difference before treatment in the basic geometry knowledge of members of the experimental group and the control group as measured by the Entering Geometry Student Test (EGST).

### Hypothesis 2

There was no difference before treatment in the basic geometry knowledge of the female and male participants in the study as measured by the Entering Geometry Student Test (EGST).

### Null Hypothesis 3

There was no difference in the attitudes of students in the experimental group and the control group toward mathematics before treatment in any of the following six categories, as determined by the University of Minnesota's Mathematics Attitude Inventory (MAI).

- 3.1 Perception of the Mathematics Teacher
- 3.2 Anxiety towards Mathematics
- 3.3 Value of Mathematics in Society
- 3.4 Self-Concept in Mathematics
- 3.5 Enjoyment of Mathematics
- 3.6 Motivation in Mathematics

#### Hypothesis 4

There was no difference in the attitudes of students in the experimental group and the control group in any of the six categories of the University of Minnesota's Mathematics Attitude Inventory (MAI), after ten weeks of treatment.

#### Hypothesis 5

There was no difference in the attitudes of students from the experimental group in any of the six categories in the MAI after ten weeks of treatment, when compared to their attitudes at the beginning of the study.

#### Hypothesis 6

There was no difference in the attitudes of students from the control group in any of the six categories in the MAI after ten weeks of treatment, when compared to their attitudes at the beginning of the study.

#### Hypothesis 7

There was no difference in the attitudes of female students and male students in the experimental group before treatment in any of the six categories of the University of Minnesota's Mathematics Attitude Inventory (MAI).

### Hypothesis 8

There was no difference in the attitudes of female students and male students in the experimental group after treatment in any of the six categories of the University of Minnesota's Mathematics Attitude Inventory (MAI).

### Hypothesis 9

There was no difference in the attitudes of female students and male students in the control group before treatment, in any of the six categories of the University of Minnesota's Mathematics Attitude Inventory (MAI).

### Hypothesis 10

There was no difference in the attitudes of female students and male students in the control group after treatment, in any of the six categories of the University of Minnesota's Mathematics Attitude Inventory (MAI).

### Hypothesis 11

There was no difference in the ten-week average POW scores (WK10AV) achieved by students in the experimental group and the control group after they have completed the POW for ten weeks.

### Hypothesis 12

There was no difference in the ten-week average POW scores (WK10AV) achieved by female and male participants after they have completed the POW for ten weeks.

### Hypothesis 13

There was no difference in the ten-week average POW scores (WK10AV) achieved by members of the experimental group with respect to the amount of time students spent using Math Forum Archives.

### Hypothesis 14

There was no difference in the problem-solving achievement of the members of the experimental group with respect to the amount of time students spent using the Math Forum Archives, as measured by the McBride Problem Solving Test (PST) after treatment.

### Hypothesis 15

There was no difference in the ten-week average POW scores (WK10AV) achieved by members of the experimental group with respect to the amount of time students spent communicating with others via Internet E-mail on the solution of the POW.

### Hypothesis 16

There was no difference in the problem-solving achievement of the members of the experimental group with respect to the amount of time students spent communicating with others via Internet E-mail on the solution of the POW's, after ten weeks of treatment, as measured by the PST.

### Hypothesis 17

There was no difference in the problem-solving achievement of the members of the experimental group and the control group, as measured by the PST, after ten weeks of treatment.

### Hypothesis 18

There was no difference in the problem-solving achievement of the female and the male participants, as measured by the PST, after ten weeks of treatment.

### Limitations and Delimitations

This study was delimited in the amount of time that the MATH FORUM POW was available to the students in the experimental and control groups. The period of time was limited to ten weeks. Another delimitation was the fact that the study was limited to high schools in the state of Montana. The study was limited to students who were currently enrolled in geometry. A major limitation was that fact that the experimental group had to have access to the MATH FORUM on the Internet, and that time had to be

available for the participating students in the experimental group to access the MATH FORUM Archives and communicate via Internet E-mail with others who were attempting to solve the current POW.

The three categories investigated were (a) the effect that working a MATH FORUM POW for ten weeks had on problem-solving achievement, (b) the effect that using the Math Forum Archives and communication with others via Internet E-mail regarding solution of the Math Forum POW has on problem-solving achievement, and (c) the effect that a ten week experience in solving the Math Forum POW has on the attitudes of students toward mathematics.

Contaminating variables were (a) the teaching ability of the classroom geometry teacher for each group, (b) mathematics academic ability of students involved in the study, (c) amount of time available for students to use the Math Forum Archives and communicate with others via Internet E-mail during the time allocated for weekly solution of the POW, (d) amount of time that each respective geometry teacher spent on problem-solving not related to the POW, (e) prior exposure to geometrical concepts by students in each group, (f) parental involvement with the students regarding the teaching of problem-solving skills, (g) relevance and difficulty of the Problem of the Week, (h) grade level that the students were in, (i) socioeconomic status, (j) consistency of the teachers in delivering the POW to both the experimental and control groups, (k) maturation of the students involved over the ten-week period, (l) consistency of the MATH FORUM to provide the POW in a timely manner, (m) closeness of the POW's to concepts being taught in the respective geometry classes involved, (n) the attitudes of the participating geometry

teachers toward problem-solving, (o) the attitudes toward problem-solving of others communicating with students on the MATH FORUM in the solution of weekly POW's, (p) changes in attitudes of members of the control group due to the fact that they were not given to opportunity to use the Math Forum Archives or communication with others via Internet E-mail, (q) attitude of the parents of participating students toward geometry and problem-solving, (r) possibility that taking the same mathematics attitude test before the ten-week period will effect the result achieved on the this same test after the ten-week period, (s) lack of prior experience using computers and the Internet may influence reluctance of students to engage in meaningful dialogue with others regarding the POW, and (t) the improper documentation of the time spent by members of the experimental group on Archive use and communication via Internet E-mail, might contaminate data.

If it were possible to select high school geometry classrooms who had the same teacher for both the experimental groups and the control groups, this would control for teacher bias. Matching students according to their previously measured mathematics academic ability would control for that variable. By controlling the amount of time allowed for Internet communication, several other important variables could be controlled. If the participants were limited to tenth grade students only, another variable could be eliminated. Close coordination between the researcher, the participating teachers, and the ten week MATH FORUM POW producers would allow for a consistency concerning how these problems relate to the traditional geometry classroom content. It was possible that the attitudes of the teachers and parents toward geometry and problem-solving might have

provided additional relevant data. One additional limitation is that the McBride Geometry Problem Solving Test was validated on basically all-white, non-rural subjects.

## CHAPTER 3

## DATA ANALYSIS AND FINDINGS

Introduction

The research findings related in this chapter are organized as follows (a) Basic geometry knowledge of the participating students before treatment, analyzed by method of treatment and gender, (b) attitudes of students towards mathematics, analyzed by method of treatment and gender, before and after treatment, (c) average mathematics achievement by participating students on ten of the Math Forum POW's (WK10AV) analyzed by method of treatment and gender, (d) the effect of using the Math Forum's Archives and communication by Internet E-mail on the WK10AV and achievement on the McBride Problem Solving Test (PST), and (e) achievement on the PST after ten weeks of treatment, analyzed by method of treatment and gender. Criteria for the rejection of all null hypotheses was set at  $p \leq .05$  in Chapter 2. Hypotheses 1, 2, and 11 - 16 were analyzed using the statistical software package called Statistical Analysis Software (SAS). Hypotheses 3 - 10 were analyzed using statistical software available in Microsoft Excel.

Hypotheses FindingsHypothesis 1

There was no difference before treatment in the basic geometry knowledge of members of the experimental group and the control group as measured by the Entering Geometry Student Test (EGST).

### Analysis

The mean score for the experimental group was 15.94, (N= 53). The mean score for the control group was 17.45, (N=51). In an ANOVA, with the EGST score as the dependent variable, the Between Groups Pr>F value obtained for Method was .0037.

Table 1. Three Factor Analysis of Variance with the Entering Geometry Student Test as the dependent variable

Source	df	SS	MS	F Value	Pr>F
Instructor	2	14.1487	7.0743	1.15	0.3218
Method	1	54.6803	54.6803	8.87	0.0037
Method*Instructor	2	8.1980	4.0990	0.66	0.5167
Gender	1	0.3663	0.3663	0.06	0.8079
Instructor*Gender	2	13.7571	6.8785	1.12	0.3320
Method*Gender	1	0.0822	0.0822	0.01	0.9083

### Decision

Hypothesis 1 was rejected. There was a statistically significant difference before treatment in the basic geometry knowledge of members of the experimental group and the control group on the EGST, as indicated by the p-value of .0037 for Method in the ANOVA in Table 1.

### Hypothesis 2

There was no difference before treatment in the basic geometry knowledge of the female and male participants in the study as measured by the Entering Geometry Student Test (EGST).

### Analysis

The mean score for the female participants was 16.52, (N= 54). The mean score for the male participants was 16.86, (N=50). In the ANOVA in Table 2, with the EGST score as the dependent variable, the Between groups Pr>F for Gender was .8079.

Table 2. Three Factor Analysis of Variance with the Entering Geometry Student Test as the dependent variable

Source	df	SS	MS	F Value	Pr>F
Instructor	2	14.1487	7.0743	1.15	0.3218
Method	1	54.6803	54.6803	8.87	0.0037
Method*Instructor	2	8.1980	4.0990	0.66	0.5167
Gender	1	0.3663	0.3663	0.06	0.8079
Instructor*Gender	2	13.7571	6.8785	1.12	0.3320
Method*Gender	1	0.0822	0.0822	0.01	0.9083

### Decision

Hypothesis 2 was retained. There was no statistically significant difference in the basic geometry knowledge of female and male participants before treatment, as measured by the Entering Geometry Student Test (EGST). A Between groups p-value of .8079 for Gender in Table 2 confirms this decision.

### Hypothesis 3

There was no difference in the attitudes of students in the experimental group and the control group toward mathematics before treatment in any of the following six categories, as determined by the University of Minnesota's Mathematics Attitude Inventory (MAI).

- (1) Perception of the Mathematics Teacher (PMT)
- (2) Anxiety towards Mathematics (ATM)
- (3) Value of Mathematics in Society (VMS)
- (4) Self-Concept in Mathematics (SCM)
- (5) Enjoyment of Mathematics (EIM)
- (6) Motivation in Mathematics (MIM)

### Analysis

Table 3 was constructed using data from six single factor ANOVA's which compared the attitudes of students in the experimental group and the control group toward mathematics before treatment in each of the six categories of the MAI. (experimental/control averages by category can be seen in Table 3.)

Table 3. ANOVA results for Experimental/Control group Attitudes towards Mathematics Before Treatment

Source	SS	df	MS	F	p-value	F crit	Exp Av	Ctl Av
PMT	61.1771	1	61.1771	2.9280	0.0901	3.9342	22.6	24.2
ATM	18.3304	1	18.3304	1.7432	0.1897	3.9342	12.6	11.7
VMS	96.3375	1	96.3375	7.1128	0.0089	3.9342	21.1	23.0
SCM	83.9875	1	83.9875	4.9809	0.0278	3.9342	15.3	17.1
EOM	141.7277	1	141.7277	7.6309	0.0068	3.9342	15.5	17.9
MIM	1.3674	1	1.3674	0.3210	0.5722	3.9342	7.2	6.9

### Decision

Categories PMT, ATM, and MIM of Hypotheses 3 were retained. It can be seen in Table 3 that there was no statistically significant difference in the attitudes of students in the experimental group and the control group before treatment regarding their Perception of the Math Teacher, Anxiety toward Mathematics, and Motivation in Mathematics.

Categories VMS, SCM, and EOM of Hypothesis 3 were rejected. It can be seen from Table 3 that there was a statistically significant difference in the attitudes of students in the experimental group and the control group before treatment regarding their Value of Mathematics to Society, Self -Concept in Math, and Enjoyment of Mathematics.

#### Hypothesis 4

There was no difference in the attitudes of students in the experimental group and the control group in any of the six categories of the MAI, after ten weeks of treatment.

#### Analysis

Table 4 was constructed using data from six single factor ANOVA's which compared the attitudes of students in the experimental group and the control group toward mathematics after treatment in each of the six categories specified in the MAI. (experimental/control averages by category can be seen in Table 4.)

Table 4. ANOVA results for Experimental/Control group Attitudes towards Mathematics After Treatment

Source	SS	df	MS	F	p-value	F crit	Exp Av	Ctl Av
PMT	22.8961	1	22.8961	1.0450	0.3091	3.9342	22.4	23.4
ATM	14.8331	1	14.8331	1.6458	0.2024	3.9342	12.7	12.0
VMS	85.6899	1	85.6899	4.8707	0.0296	3.9342	21.3	23.1
SCM	55.4466	1	55.4466	3.7744	0.0548	3.9342	15.2	16.7
EOM	80.8371	1	80.8371	4.1974	0.0431	3.9342	15.5	17.2
MIM	1.8135	1	1.8135	0.4644	0.4971	3.9342	7.3	7.0

### Decision

Categories PMT, ATM, SCM, and MIM of Hypothesis 4 were retained. It can be seen in Table 4 that there was no statistically significant difference in the attitudes of students in the experimental group and the control group after treatment regarding their Perception of the Teacher, Anxiety toward Mathematics, Self -Concept in Math, and Motivation in Mathematics.

Categories VMS and EOM of Hypothesis 4 were rejected. There was a statistically significant difference in the attitudes of students in the experimental and the control groups after treatment regarding their Value of Mathematics to Society and Enjoyment of Mathematics.

### Hypothesis 5

There was no difference in the attitudes of students from the experimental group in any of the six categories in the MAI after ten weeks of treatment, when compared to their attitudes at the beginning of the study.

### Analysis

Table 5 was constructed using data from six single factor ANOVA's which compared the attitudes of students in the experimental group toward mathematics before and after treatment in each of the six categories of the MAI. (Before/After averages by category can be seen in Table 5.)

Table 5. ANOVA results for Experimental group Attitudes towards Mathematics Before and After Treatment

Source	SS	df	MS	F	p-value	F crit	Av Before	Av After
PMT	0.9434	1	0.9434	0.0379	0.8460	3.9324	22.6	22.4
ATM	0.6038	1	0.6038	0.0541	0.8166	3.9324	12.6	12.7
VMS	1.1415	1	1.1415	0.0569	0.8120	3.9324	21.1	21.3
SCM	0.2358	1	0.2358	0.0130	0.9093	3.9324	15.3	15.2
EOM	0.1509	1	0.1509	0.0075	0.9310	3.9324	15.5	15.5
MIM	0.3396	1	0.3396	0.0665	0.7970	3.9324	7.2	7.3

### Decision

Categories PMT, ATM, VMS, SCM, EOM and MIM of Hypothesis 5 were retained. It can be seen in Table 5 that there was no statistically significant difference in the attitudes of students in the experimental group after treatment regarding their Perception of the Math Teacher, Anxiety toward Mathematics, Value of Mathematics to Society, Self -Concept in Math, Enjoyment of Mathematics and Motivation in Mathematics, when compared to their attitudes before treatment.

### Hypothesis 6

There was no difference in the attitudes of students from the control group in any of the six categories in the MAI after ten weeks of treatment, when compared to their attitudes at the beginning of the study.

### Analysis

Table 6 was constructed using data from six single factor ANOVA's which compared the attitudes of students in the control group toward mathematics before and

after treatment in each of the six categories of the MAI. (Before/After averages by category can be seen in Table 6.)

Table 6. ANOVA results for Control group Attitudes towards Mathematics Before and After Treatment

Source	SS	df	MS	F	p-value	F crit	Av Before	Av After
PMT	15.6863	1	15.6863	0.8829	0.3497	3.9362	24.2	23.4
ATM	1.4118	1	1.4118	0.1610	0.6810	3.9362	11.7	12.0
VMS	0.2451	1	0.2451	0.0225	0.8810	3.9362	23.0	23.1
SCM	4.7451	1	4.7451	0.3545	0.5529	3.9362	17.1	16.7
EOM	10.6765	1	10.6765	0.6010	0.4400	3.9362	17.9	17.2
MIM	0.1569	1	0.1569	0.0520	0.8201	3.9362	6.9	7.0

### Decision

Categories PMT, ATM, VMS, SCM, EOM and MIM of Hypothesis 6 were retained. It can be seen in Table 6 that there was no statistically significant difference in the attitudes of students in the control group after treatment regarding their Perception of the Math Teacher, Anxiety toward Mathematics, Value of Mathematics to Society, Self - Concept in Math, Enjoyment of Mathematics and Motivation in Mathematics, when compared to their attitudes before treatment

### Hypothesis 7

There was no difference in the attitudes of female students and male students in the experimental group before treatment in any of the six categories of the MAI.

### Analysis

Table 7 was constructed using data from six single factor ANOVA's which compared the attitudes of female students and male students in the experimental group before treatment in each of the six categories of the MAI. (Female/Male averages by category can be seen in Table 7.)

Table 7. ANOVA results for Female/Male attitudes towards Mathematics for members of the Experimental group Before Treatment

Source	SS	df	MS	F	p-value	F crit	Female Av	Male Av
PMT	119.496	1	119.496	5.3134	0.0253	4.0304	21.4	24.5
ATM	42.7548	1	42.7548	3.7203	0.0593	4.0304	13.3	11.5
VMS	31.6072	1	31.6072	1.8811	0.1762	4.0304	20.5	22.0
SCM	151.7752	1	151.7752	9.2357	0.0037	4.0304	14.0	17.4
EOM	73.4133	1	73.4133	3.9674	0.0518	4.0304	14.6	17.0
MIM	6.1496	1	6.1496	1.0866	0.3022	4.0304	6.9	7.6

### Decision

Categories ATM, VMS, EOM, and MIM of Hypothesis 7 were retained. It can be seen in Table 7 that there was no statistically significant difference in the attitudes of female students and male students in the experimental group before treatment regarding their Anxiety toward Mathematics, Value of Math to Society, Enjoyment of Math, and Motivation in Mathematics.

Categories PMT and SCM of Hypothesis 7 were rejected. There was a statistically significant difference in the attitudes of female students and male students in the experimental group before treatment regarding in their Perception of the Teacher and Self-Concept in Math.

### Hypothesis 8

There was no difference in the attitudes of female students and male students in the experimental group after treatment in any of the six categories of the MAI.

### Analysis

Table 8 was constructed using data from six single factor ANOVA's which compared the attitudes of female students and male students in the experimental group after treatment in each of the six categories of the MAI. (Female/Male averages by category can be seen in Table 8.)

Table 8. ANOVA results for Female/Male Attitudes towards Mathematics for members of the Experimental group After Treatment

Source	SS	df	MS	F	p-value	F crit	Female Av	Male Av
PMT	138.376	1	138.376	5.9572	0.0182	4.0304	21.1	24.4
ATM	55.1888	1	55.1888	5.8993	0.0187	4.0304	13.6	11.5
VMS	60.3424	1	60.3424	2.7023	0.1064	4.0304	20.4	22.6
SCM	151.6447	1	151.6447	10.4771	0.0021	4.0304	13.9	17.3
EOM	133.1897	1	133.1897	7.2881	0.0094	4.0304	14.2	17.4
MIM	0.4745	1	0.4745	0.1026	0.7500	4.0304	7.2	7.4

### Decision

Categories VMS and MIM of Hypothesis 8 were retained. It can be seen from Table 8 that there was no statistically significant difference in the attitudes of female students and male students in the experimental group after treatment regarding their Value of Math to Society and Motivation in Mathematics.

Categories PMT, ATM, SCM, and EOM of Hypothesis 8 were rejected. There was a statistically significant difference in the attitudes of female students and male

students in the experimental group after treatment regarding their Perception of the Math Teacher, Anxiety toward Mathematics, Self -Concept in Math, and Enjoyment of Math.

#### Hypothesis 9

There was no difference in the attitudes of female students and male students in the control group before treatment, in any of the six categories of the University of Minnesota's Mathematics Attitude Inventory (MAI).

#### Analysis

Table 9 was constructed using data from six single factor ANOVA's which compared the attitudes of female students and male students in the control group before treatment in each of the six categories of the MAI. (Female/Male averages by category can be seen in Table 9.)

#### Decision

Categories PMT, ATM, VMS, EOM., AND MIM of Hypothesis 9 were retained. It can be seen in Table 9 that there was no statistically significant difference in the attitudes of female students and male students in the control group before treatment regarding their Perception of the Math Teacher, Anxiety toward Mathematics, Value of Math to Society, Enjoyment of Math and Motivation in Mathematics.

Category SCM of Hypothesis 9 was rejected. It can be seen in Table 9 that there was a statistically significant difference in the attitudes of female students and male students in the control group before treatment regarding their Self -Concept in Math.

Table 9. ANOVA results for Female/Male Attitudes towards Mathematics for members of the Control group Before Treatment

Source	SS	df	MS	F	p-value	F crit	Female Av	Male Av
PMT	7.1401	1	7.1401	0.4080	0.5260	4.0384	23.7	24.5
ATM	7.3791	1	7.3791	0.8287	0.3671	4.0384	12.2	11.4
VMS	1.5697	1	1.5697	0.1565	0.6941	4.0384	22.8	23.2
SCM	81.9561	1	81.9561	6.1965	0.0162	4.0384	15.7	18.2
EOM	18.9869	1	18.9869	1.0839	0.3029	4.0384	17.2	18.4
MIM	0.8571	1	0.8571	0.3025	0.5848	4.0384	6.8	7.0

#### Hypothesis10

There was no difference in the attitudes of female students and male students in the control group after treatment, in any of the six categories of the MAI.

#### Analysis

Table 10 was constructed using data from six single factor ANOVA's which compared the attitudes of female students and male students in the control group after treatment in each of the six categories of the MAI. (Female/Male averages by category can be seen in Table 10.)

#### Decision

Categories PMT, ATM, VMS, SCM, EOM, and MIM of Hypothesis 10 were retained. There was no statistically significant difference in the attitudes of female students and male students in the control group after treatment regarding their Perception of the

Math Teacher, Anxiety about Mathematics, Value of Math to Society, Self -Concept in Math, Enjoyment of Math and Motivation in Mathematics.

Table 10. ANOVA results for Female/Male Attitudes towards Mathematics for members of the Control group After Treatment

Source	SS	df	MS	F	p-value	F crit	Female Av	Male Av
PMT	13.92	1	13.92	0.7596	0.3877	4.0384	22.8	23.8
ATM	4.4146	1	4.4146	0.5654	0.4557	4.0384	12.3	11.7
VMS	17.0120	1	17.0120	1.4415	0.2357	4.0384	22.5	23.6
SCM	21.8406	1	21.8406	1.8239	0.1831	4.0384	16.0	17.3
EOM	9.9852	1	9.9852	0.5503	0.4618	4.0384	16.7	17.6
MIM	0.7194	1	0.7194	0.2186	0.6422	4.0384	7.1	6.9

### Hypothesis 11

There was no difference in the ten-week average POW scores (WK10AV) achieved by students in the experimental group and the control group after they have completed the POW for ten weeks.

### Analysis

Hypothesis 11 was analyzed by using a single factor Analysis of Variance with the WK10AV as the dependent variable as shown in Table 11 A, and by using a three factor Analysis of Covariance with the WK10AV as the dependent variable and the Entering Geometry Student Test as the covariate, as shown in Table 11 B. The mean score for the experimental group was 1.25 (N= 53). The mean score for the control group was 1.65 (N=51). From the ANOVA in Table 11 A, with theWK10AV score as the dependent variable, the Between Groups P-value obtained was 7.2E-08. In the ANCOVA in Table 11B the Between Groups P-value obtained for Method was .0001.

Table 11 A. Analysis of Variance Table with the Ten Week POW Average (WK10AV) as the dependent variable

SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>
EXP WK10AV	53	66	1.25	0.1082
CTL WK10AV	51	84	1.65	0.1385

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	4.1546	1	4.1546	33.74	7.2E-08	3.93425
Within Groups	12.5576	102	0.1231			
Total	16.7122	103				

Table 11 B. Three Factor Analysis of Covariance Table with the Ten Week POW Average (WK10AV) as the dependent variable and the EGST score as a covariate

<i>Source</i>	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F Value</i>	<i>Pr&gt;F</i>
Method	1	3.7139	3.7139	16.03	0.0001
Instructor	2	0.6273	0.3136	1.35	0.2633
Method*Instructor	2	0.0694	0.0347	0.15	0.8612
Gender	1	0.0396	0.0396	0.17	0.6801
Method*Gender	1	1.6211	1.6211	7.00	0.0096
Instructor*Gender	2	0.1906	0.0953	0.41	0.6639
EGST	1	1.5052	1.5052	6.50	0.0124

\* Statistically significant ( $p \leq .05$ )

Decision

Using the analysis from Table 11 A, Hypothesis 11 was rejected. There was a significant difference in the ten-week average POW scores (WK10AV) of members of the experimental group and the control group. A Between groups p-value of 7.2E-08 in Table 11 A confirmed the decision.

Using the analysis from Table 11 B, Hypothesis 11 was also rejected. There was a significant difference in the ten-week average Problem of the Week scores (WK10AV) of

members of the experimental group and the control group when the Entering Geometry Student Test was used as a covariate. A Between groups p-value of .0001 for Method in Table 11 B confirmed the decision.

### Hypothesis 12

There was no difference in the ten-week average POW scores (WK10AV) achieved by female and male participants after they have completed the POW for ten weeks.

### Analysis

Hypothesis 12 was analyzed by using a single factor Analysis of Variance with the WK10AV as the dependent variable as shown in Table 12 A, and by using a three factor Analysis of Covariance with the WK10AV as the dependent variable and the Entering Geometry Student Test as the covariate, as shown in Table 12 B. The mean score for the WK10AV for females was 1.43, (N= 54). The mean score for the WK10AV for males was 1.46, (N= 50). In the ANOVA in Table 12 A, with the WK10AV score as the dependent variable, the Between Groups P-value obtained was .7230. In the ANCOVA in Table 12 B, with the WK10AV as the dependent variable and the Entering Geometry Student Test as the covariate, the Between Groups P-value obtained for Gender was .6801.

Table 12 A Analysis of Variance Table with the Ten Week POW Average (WK10AV) as the dependent variable

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>
Female WK10AV	54	77.1	1.43	0.1756
Male WK10AV	50	72.8	1.46	0.1506

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	0.0206	1	0.0206	0.1264	0.7230	3.9343
Within Groups	16.6915	102	0.1636			
Total	16.7122	103				

Table 12 B. Three Factor Analysis of Covariance Table with the Ten Week POW Average (WK10AV) as the dependent variable and the EGST as a covariate

<i>Source</i>	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F Value</i>	<i>Pr&gt;F</i>
Method	1	3.7139	3.7139	16.03	0.0001
Instructor	2	0.6273	0.3136	1.35	0.2633
Method*Instructor	2	0.0694	0.0347	0.15	0.8612
Gender	1	0.0396	0.0396	0.17	0.6801
Method*Gender	1	1.6211	1.6211	7	0.0096
Instructor*Gender	2	0.1906	0.0953	0.41	0.6639
EGST	1	1.5052	1.5052	6.5	0.0124

\* Statistically significant ( $p \leq .05$ )

### Decision

Using the analysis from Table 12 A, Hypothesis 12 was retained. There was no significant difference in the WK10AV for female students and male students after ten weeks of treatment. A Between groups p-value of .7230 in Table 12 A confirmed the decision.

Using the analysis from Table 12 B, Hypothesis 12 was also retained. There was no significant difference in the ten-week average Problem of the Week scores (WK10AV)

for female students and male students after ten weeks of treatment when the Entering Geometry Student Test is used as a covariate. A Between groups P-value of .6801 in Table 12 B confirmed the decision.

### Hypothesis13

There was no difference in the ten-week average POW scores (WK10AV) achieved by members of the experimental group with respect to the amount of time students spent using Math Forum Archives.

### Analysis

For this analysis, the amount of time spent using the Math Forum Archives by students in the experimental group was used as a covariate. In an ANCOVA in Table 13, with the WK10AV score as the dependent variable, the Within Groups P-value obtained for Archive was .9501.

Table 13. Three Factor Analysis of Covariance Table with the Ten Week POW Average (WK10AV) as the dependent variable and the time of Archive use and EGST as covariates

Source	df	SS	MS	F Value	Pr>F
Instructor	2	0.2389	0.1195	1.53	0.2267
Archive	1	0.0003	0.0003	0.00	0.9501
Archive*Instructor	2	0.4165	0.2082	2.67	0.0799
Gender	1	0.0505	0.0505	0.65	0.4249
EGST	1	1.3537	1.3537	17.38	0.0001

Statistically significant ( $p \leq .05$ )

### Decision

Hypothesis 13 was retained. From the ANCOVA in Table 13, with a Within Groups P-value of .9501 for Archives, there was no significant difference in the WK10AV of members of the experimental group with respect to the amount of time they spent using the Math Forum Archives.

### Hypothesis 14

There was no difference in the problem-solving achievement of the members of the experimental group with respect to the amount of time they spent using the Math Forum Archives, as measured by the McBride Problem Solving Test (PST) after treatment.

### Analysis

For this analysis, the amount of time spent using the Math Forum Archives by students in the experimental group was used as a covariate. In the ANCOVA in Table 14, with the PST score as the dependent variable, the Within Groups P-value obtained for Archive was .9068.

Table 14. Three Factor Analysis of Covariance Table with the PST as the dependent variable and the time of Archive use and the EGST as covariates

Source	df	SS	MS	F Value	Pr>F
Instructor	2	260.6600	130.3300	0.26	0.7748
Archive	1	7.0361	7.0361	0.01	0.9068
Archive*Instructor	2	93.5841	46.7920	0.09	0.9122
Gender	1	437.0417	437.0417	0.86	0.3585
EGST	1	4043.3579	4043.3579	7.96	0.0071

Statistically significant ( $p \leq .05$ )

### Decision

Hypothesis 14 was retained. From the ANCOVA in Table 14, with a Within Groups p-value of .9068 for Archives, there was no significant difference in the PST score for students with respect to the amount of time they use the Math Forum Archives.

### Hypothesis 15

There was no difference in the ten-week average POW scores (WK10AV) achieved by members of the experimental group with respect to the amount of time students spent communicating with others via Internet E-mail on the solution of the POW's.

### Analysis

All students in the experimental group had access to the use of the Internet for Email communication during the twenty minutes allowed during class each week for solving the POW. During the entire ten-week period, only seven out of the fifty-three participating students communicated with others via E-mail in the process of solving the POW.

### Decision

Due to the fact that only seven of the fifty-three participants in the experimental group ever used Internet Email during the entire ten-week period of the study, it was impossible to determine the effect of the amount of time students spent using Internet E-

mail for communication with others in the solution of the POW on their ten-week average score on the POW (WK10AV). Therefore Hypothesis 15 was neither retained nor rejected

### Hypothesis 16

There was no difference in the problem-solving achievement of the members of the experimental group with respect to the amount of time students spent communicating with others via Internet E-mail on the solution of the POW's, as measured by the PST, after ten weeks of treatment.

### Analysis

All students in the experimental group had access to the use of the Internet for E-mail communication during the twenty minutes allowed each week during class for solving the POW. During the entire ten-week period, only seven out of the fifty-three participating students communicated with others via E-mail in the process of solving the POW.

### Decision

Due to the fact that only seven of the fifty-three participants in the experimental group ever used Internet E-mail during the entire ten-week period of the study, it was impossible to determine the effect of the amount of time students spent using Internet Email for communication with others in the solution of the POW's on their problem-solving achievement as measured by the PST after treatment. Therefore Hypothesis 16 was neither retained nor rejected.

### Hypothesis 17

There was no difference in the problem-solving achievement of the members of the experimental group and the control group, as measured by the PST, after ten weeks of treatment.

### Analysis

Hypothesis 17 was analyzed by using a single factor Analysis of Variance with the PST as the dependent variable as shown in Table 15 A, and by using a three factor Analysis of Covariance with the PST as the dependent variable and the Entering Geometry Student Test as a covariate, as shown in Table 15 B. The mean score for the PST for the experimental group was 81.49, (N=53). The mean score for the PST for the control group was 91.41, (N= 51). From the ANOVA in Table 15 A with the PST score as the dependent variable, the Between Groups P-value obtained was .0531.

From the ANCOVA in Table 15 B, with the PST score as the dependent variable and the EGST as the covariate, the Between Groups P-value obtained for Method was .8247.

Table 15 A. Analysis of Variance of the Experimental and Control groups with the PST score as the dependent variable

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>
PST Experimental	53	4319	81.49	551.716
PST Control	51	4662	91.41	789.407

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	2558.2	1	2558.24	3.8283	0.0531	3.9342
Within Groups	68159.6	102	668.23			
Total	70717.8	103				

Table 15 B. Three Factor Analysis of Covariance Table with the PST score as the dependent variable and the EGST as a covariate

Source	df	SS	MS	F Value	Pr>F
Method	1	31.4548	31.4548	0.05	0.8247
Instructor	2	1446.7009	723.3504	1.13	0.3260
Method*Instructor	2	322.2912	161.1456	0.25	0.7772
Gender	1	758.6463	758.6463	1.19	0.2782
Method*Gender	1	2.9358	2.9358	0.00	0.9460
Instructor*Gender	2	1051.4412	525.7206	0.82	0.4416
EGST	1	6486.1122	6486.1122	10.17	0.0019
EGST*Method	1	9.9518	9.9518	0.02	0.9008

\* Statistically significant ( $p \leq .05$ )

### Decision

Using the analysis from Table 15 A, Hypothesis 17 was retained. From the ANOVA in table 15 A, with a Between- Groups p-value of .0531, there was no significant difference in the PST scores for students in the experimental group and students in the control group at the  $p \leq .05$  level.

Using the analysis from Table 15 B, Hypothesis 17 was also retained. There was no significant difference in the PST score of members of the experimental group and the control group when the PST score is the dependent variable and the Entering Geometry Student Test is used as a covariate. A Between groups P-value of .8247 for Method in Table 15 B confirmed the decision.

### Hypothesis18

There was no difference in the problem-solving achievement of the female and the male participants, as measured by the PST, after ten weeks of treatment.

### Analysis

Hypothesis 18 was analyzed by using a single factor Analysis of Variance with the PST as the dependent variable as shown in Table 16 A, and by using a three factor Analysis of Covariance with the PST as the dependent variable and the Entering Geometry Student Test as a covariate, as shown in Table 16 B. The mean score for the females on the PST was 82.76, (N= 54). The mean score for the males on the PST was 90.24, (N= 50). From the ANOVA in Table 16 A with the PST score as the dependent variable, the Between Groups P-value obtained was .1466.

From the ANCOVA in Table 16B, with the PST score as the dependent variable, and the EGST as a covariate, the Between Groups P-value obtained for Gender was .2782.

Table 16 A. Analysis of Variance of Female and Male Participants with the PST score as the dependent variable

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>		
PST Female	54	4469	82.76	628.41		
PST Male	50	4512	90.24	733.86		

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	1452.85	1	1452.85	2.1394	0.1466	3.9342
Within Groups	69265	102	679.07			
Total	70717.8	103				

Table 16 B. Three Factor Analysis of Covariance Table with the PST score as the dependent variable and the EGST as a covariate

Source	df	SS	MS	F Value	Pr>F
Method	1	31.4548	31.4548	0.05	0.8247
Instructor	2	1446.7009	723.3504	1.13	0.3260
Method*Instructor	2	322.2912	161.1456	0.25	0.7772
Gender	1	758.6463	758.6463	1.19	0.2782
Method*Gender	1	2.9358	2.9358	0.00	0.9460
Instructor*Gender	2	1051.4412	525.7206	0.82	0.4416
EGST	1	6486.1122	6486.1122	10.17	0.0019
EGST*Method	1	9.9518	9.9518	0.02	0.9008

\* Statistically significant ( $p \leq .05$ )

### Decision

Using the analysis from Table 16 A, Hypothesis 18 was retained. From the ANOVA in table 16 A, with a Between- Groups P-value of .1466, there was no significant difference in the PST score for female students and male students.

Using the analysis form Table 16 B, Hypothesis 18 was also retained. There was no significant difference in the PST score for female students and male students when the PST score was used as the dependent variable and the Entering Geometry Student Test was used as a covariate. A Between groups P-value of .2782 for Gender in Table 16 B confirmed the decision.

### Summary of the Findings

Table 17 summarizes the retention or rejection of Hypotheses 1,2, 11-14, 17 and 18. In summary, Hypotheses 13 and 14 were analyzed with the Statistical Analysis System (SAS) software package, and from this analysis, the amount of time students used the Archives

did not have a significant effect on student achievement on either the WK10AV or the PST, so both Hypotheses 13 and 14 were retained. Due to the fact that only seven of the fifty-three participants in the experimental group ever used Internet E-mail during the entire ten-week period of the study, it was impossible to determine the effect of the amount of time students spent using Internet E-mail for communication with others in the solution of the POW's on either their ten-week average scores on the POW's (WK10AV) or their problem-solving achievement as measured by the PST after ten weeks of participation. Therefore Hypotheses 15 and 16 was neither retained nor rejected.

Table 17. Summary of retention and rejection of Hypotheses 1, 2 and 11-16

Hypothesis	Dep. Var.	Method/Gender- Avg.	p-value	Ret/Rej Hyp
Hypothesis 1	EGST	Exp. - 15.94	0.0037	Reject
		Ctl. - 17.45		
Hypothesis 2	EGST	Female - 16.52	0.8079	Retain
		Male - 16.86		
Hypothesis 11	WK10AV	Exp. - 1.25	7.2E-08	Reject
		Ctl. - 1.65		
Hypothesis 12	WK10AV	Female - 1.43	0.7230	Retain
		Male - 1.46		
Hypothesis 13	WK10AV	Time of Archive use	0.9501	Retain
Hypothesis 14	PST	Time of Archive use	0.9068	Retain
Hypothesis 17	PST	Exp. - 81.49	0.0531	Retain
		Ctl. - 91.41		
Hypothesis 18	PST	Female - 82.76	0.1466	Retain
		Male - 90.24		

Tables 18 - 25 summarize the retention and rejection of all categories of Hypotheses 3-10

Table 18. Summary of Hypothesis 3 - Exp./Ctl. group Attitudes Before Treatment

Source	Exp Av	Ctl Av	p-value	Ret./Rej. Hyp.
Perception of Math Teacher	22.6	24.2	0.0901	Retain
Anxiety toward Math	12.6	11.7	0.1897	Retain
Value of Math to Society	21.1	23.0	0.0089	Reject
Self-Concept about Math	15.3	17.1	0.0278	Reject
Enjoyment of Math	15.5	17.9	0.0068	Reject
Motivation in Math	7.2	6.9	0.5722	Retain

Table 19. Summary of Hypothesis 4 - Exp./Ctl. group Attitudes After Treatment

Source	Exp Av	Ctl Av	p-value	Ret./Rej. Hyp.
Perception of Math Teacher	22.4	23.4	0.3091	Retain
Anxiety toward Math	12.7	12.0	0.2024	Retain
Value of Math to Society	21.3	23.1	0.0296	Reject
Self-Concept about Math	15.2	16.7	0.0548	Retain
Enjoyment of Math	15.5	17.2	0.0431	Reject
Motivation in Math	7.3	7.0	0.4971	Retain

Table 20. Summary of Hypothesis 5 - Experimental group Attitudes Before/After Treatment

Source	Av Before	Av After	p-value	Ret./Rej. Hyp.
Perception of Math Teacher	22.6	22.4	0.8460	Retain
Anxiety toward Math	12.6	12.7	0.8166	Retain
Value of Math to Society	21.1	21.3	0.8120	Retain
Self-Concept about Math	15.3	15.2	0.9093	Retain
Enjoyment of Math	15.5	15.5	0.9310	Retain
Motivation in Math	7.2	7.3	0.7970	Retain

Table 21. Summary of Hypothesis 6 - Control group Attitudes Before/After

Source	Av Before	Av After	p-value	Ret./Rej. Hyp.
Perception of Math Teacher	24.2	23.4	0.3497	Retain
Anxiety toward Math	11.7	12.0	0.6810	Retain
Value of Math to Society	23.0	23.1	0.8810	Retain
Self-Concept about Math	17.1	16.7	0.5529	Retain
Enjoyment of Math	17.9	17.2	0.4400	Retain
Motivation in Math	6.9	7.0	0.8201	Retain

Table 22. Summary of Hypothesis 7 - Experimental group Female/Male Attitudes toward Mathematics Before Treatment

Source	Female Av	Male Av	p-value	Ret./Rej. Hyp.
Perception of Math Teacher	21.4	24.5	0.0253	Reject
Anxiety toward Math	13.3	11.5	0.0593	Retain
Value of Math to Society	20.5	22.0	0.1762	Retain
Self-Concept about Math	14.0	17.4	0.0037	Reject
Enjoyment of Math	14.6	17.0	0.0518	Retain
Motivation in Math	6.9	7.6	0.3022	Retain

Table 23. Summary of Hypothesis 8 - Experimental group Female/Male Attitudes toward Mathematics After Treatment

Source	Female Av	Male Av	p-value	Ret./Rej. Hyp.
Perception of Math Teacher	21.1	24.4	0.0182	Reject
Anxiety toward Math	13.6	11.5	0.0187	Reject
Value of Math to Society	20.4	22.6	0.1064	Retain
Self-Concept about Math	13.9	17.3	0.0021	Reject
Enjoyment of Math	14.2	17.4	0.0094	Reject
Motivation in Math	7.2	7.4	0.1026	Retain

Table 24. Summary of Hypothesis 9 - Control group Female/Male Attitudes toward Mathematics Before Treatment

Source	Female Av	Male Av	p-value	Ret./Rej. Hyp.
Perception of Math Teacher	23.7	24.5	0.5260	Retain
Anxiety toward Math	12.2	11.4	0.3671	Retain
Value of Math to Society	22.8	23.2	0.6941	Retain
Self-Concept about Math	15.7	18.2	0.0162	Reject
Enjoyment of Math	17.2	18.4	0.3029	Retain
Motivation in Math	6.8	7.0	0.5848	Retain

Table 25. Summary of Hypothesis 10 - Control group Female/Male Attitudes toward Mathematics After Treatment

Source	Female Av	Male Av	p-value	Ret./Rej. Hyp.
Perception of Math Teacher	22.8	23.8	0.3877	Retain
Anxiety toward Math	12.3	11.7	0.4557	Retain
Value of Math to Society	22.5	23.6	0.2357	Retain
Self-Concept about Math	16.0	17.3	0.1831	Retain
Enjoyment of Math	16.7	17.6	0.4618	Retain
Motivation in Math	7.1	6.9	0.6422	Retain

## CHAPTER 4

## SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Introduction

The purpose of this chapter is to summarize the key points from the previous three chapters and to analyze the results obtained. There are three sections in this chapter. The first section is a summary of the procedures used in the study. The second section presents the conclusions of the study, while the final section presents recommendations based on the findings of this research.

Summary of the Procedures Used in the Study

The purpose of this study was to determine if use of Internet-based learning resources had an effect on high school geometry student problem-solving achievement and attitudes toward mathematics. To assess the prior geometry knowledge of high school geometry students participating in the study, the Entering Geometry Student Test was administered to all students before any treatment began. The Mathematics Attitude Inventory was also administered to all participating students to determine their attitudes toward mathematics before any treatment began and again at the conclusion of the study.

Three high school geometry teachers were chosen to participate in the study. Each taught two sections of high school geometry and had access to the Internet at least one time per week during their class periods. Through a random process, the two sections

taught by each participating teacher were assigned to the experimental group or the control group.

The treatment for the study had the following specifications. Each week for ten weeks, both the experimental and the control groups received Swarthmore College's Internet-based Math Forum Problem of the Week (POW) and regular classroom instruction provided by their respective teachers. At a designated time each week for ten weeks, the students were allowed twenty minutes of class time to complete and submit their solutions to the current Problem of the Week to their teacher. All students could confer with their classmates and teachers regarding the solution of the POW. However, only students from the experimental group received access to the Internet during the twenty minutes allowed for solution of the POW each week. Internet access gave students from the experimental group the opportunity to observe solutions of prior POW's which might contain concepts needed to solve the current POW. These solutions were available at Swarthmore College's Internet web site entitled the "Math Forum Archives". The availability of the Internet also gave students from the experimental group the opportunity to communicate with others via E-mail to possibly gain insight into the solution of the current week's POW.

After ten weeks, all participating students were administered the Mathematics Attitude Inventory to see if there had been any changes in their attitudes toward mathematics. The McBride Problem Solving Test (PST), a test to determine geometry problem-solving achievement, was also administered to all participating students. Analysis of differences in achievement and attitudes before and after treatment by gender and by

method of treatment was conducted to determine the effect that use of the Internet-based learning resources had on the participating students.

### Conclusions and Implications

#### Entering Geometry Student Test Results based on Treatment and Gender

Based on the analysis of data related to Hypothesis 1 in Chapter 3, it was concluded that there was a difference between the basic geometry knowledge of members of the experimental group and the control group before treatment as measured by the Entering Geometry Student Test (EGST). The average for the control group was significantly higher. This information was important to the study since the problem-solving achievement by members of the experimental and control groups was compared after treatment by using the ten-week Problem of the Week average score (WK10AV) and the student scores on the McBride Problem Solving Test (PST). Since there was a difference in the prior basic geometry knowledge of the two participating groups, the EGST score was used in the analysis of both the WK10AV and the PST score.

From the analysis of the data related to Hypothesis 2, it was concluded that there was no difference in the prior geometry knowledge of female and male participants in the study as measured by the Entering Geometry Student Test (EGST) before treatment. In Frykholm's study concerning the effect of gender on geometry learning, gender no significant relationship with van Hiele levels. The study also concluded that gender had little or nothing to do with a student's potential in geometry (Frykholm, 1994). Findings

in the researcher's study are consistent with those documented by Frykholm on geometry achievement by gender.

#### Initial Mathematics Attitude Inventory Results Based on Treatment and Gender

Based on the analysis of data related to Hypothesis 3 concerning the attitudes of participants in the experimental group and the control group toward mathematics before treatment, it was concluded that members of the control group had significantly higher Value of Math to Society, Self-Concept about Math, and Enjoyment of Math scores than the experimental group before treatment. Perhaps these attitudes were related to the fact that students in the control group had a higher average on the EGST.

Based on the analysis of data related to Hypothesis 7 involving the effect of gender on participant attitudes toward mathematics, it was concluded that before treatment male participants in the experimental group had a higher Perception of the Math Teacher and Self-Concept about Math than the female participants in the group. Based on analysis of the data related to Hypothesis 9, it was concluded that before treatment male participants in the control group also had a higher Self-Concept about Math than the female participants in the group

It was concluded from the analyses of Hypotheses 7 and 9 that male participants from both the experimental and the control groups scored higher in their Self-Concept about Mathematics before treatment than did the female participants. This finding is consistent with the research of Orenstein, who found that there was a severe decline in

self-confidence by females by age 12 (Orenstein, 1994). However, a similar study reported finding no significant difference between female and male geometry students in their self-concept as geometry students, although differences according to success and teacher were found (Peterson, Burton, Baker, 1983). According to Sherman & Fennema, self-concept can also be related to the affective climate of the school. In schools where math is perceived as a male domain, females had lower self-concepts (Sherman & Fennema, 1977). The Software Producers Association Report on the Effectiveness of Technology in Schools found that educational technology clearly boosted student achievement, improved student attitudes and self-concept, and enhanced the quality of teacher-student relationships (Reinhardt, 1995).

#### Ten Week Averages on Math Forum Problems of the Week based on Treatment and Gender

In the analysis of data related to Hypothesis 11, the analysis of variance with the WK10AV as the dependent variable showed that the control group scored significantly higher after treatment on the WK10AV than the experimental group. When the EGST was used as a covariate, this too indicated a significant difference in the WK10AV for the experimental and the control groups. It may be interpreted that higher achievement on the WK10AV by members of the control group was due to the fact that members of the control group scored significantly higher on the EGST, which measured basic geometry knowledge before treatment. Overall, as measured by the WK10AV, no changes in the

geometry problem-solving achievement of participants in the experimental and the control groups occurred during this study.

In the analysis of data related to Hypothesis 12, the analysis of variance with the WK10AV as the dependent variable showed that there was not a significant difference in the WK10AV score achieved by female and male students. When the EGST was used as a covariate, this too indicated that there was no significant difference in the WK10AV for female and male participants. Since there wasn't a significant difference in the basic geometry knowledge of female and male participants before treatment as measured by the EGST, it could be interpreted that similar achievement on the WK10AV by female and male participants was linked to their prior knowledge. The equivalence by females and males on the WK10AV was consistent with the research done by Frykholm, who found that gender had little or nothing to do with a student's potential in geometry (Frykholm, 1994).

#### Mathematics Attitude Inventory Results Based on Treatment and Gender after Treatment

Based on the analysis of data related to Hypothesis 4 concerning the attitudes of participants in the experimental and control groups toward math after treatment, only one category out of six in the Mathematics Attitude Inventory changed during the study. It was found that although members of the control group had a higher Self-Concept about Math before treatment, there was no difference in the Self-Concept about Math for members of the experimental group and the control group after treatment. Overall, members of the control group slightly declined in their Self-Concept about Math to a point

where they were statistically equivalent to the experimental group at the end of the study. Perhaps working on the POW in the absence of ties to the Internet and electronic communication diminished the attitudes of some students in the control group. Further analysis showed that two of the three classes in the control group experienced a decline in self-concept, while the self-concept of the other class rose slightly.

Also, as specified by Tables 20 and 21, there was no change in the attitudes in any category of the MAI by members of either the experimental group or the control group after treatment when compared to their group attitudes before treatment. It was concluded that neither the students in the experimental group nor the control group developed a significant change in attitude during the course of the study. This is important, since both groups received and worked the weekly Math Forum POW and neither group seemed to react negatively to any treatment due to their participation in this study.

Based on the analysis of data related to Hypotheses 7 and 8 in Chapter 3 involving the effects of gender on the attitudes of participants in the experimental group, it was concluded that two categories in the MAI had changed during the study. Although there was no significant difference between male and female students in the experimental group regarding their Anxiety toward Math before treatment, female students did have a significantly higher Anxiety toward Math after treatment when compared to male students. The Anxiety toward Math for the male participants remained constant through the study, but the Anxiety toward Math of the females increased. This finding was consistent with

that of Bernstein, who found that math anxiety expressed by females was consistently higher than the math anxiety expressed by males (Bernstein, 1992).

There was no significant difference in the Enjoyment of Math by female and male members of the experimental group before treatment but the males had a significantly higher Enjoyment of Math than the females after treatment. The Enjoyment of Math went down for the female participants during the study, but the Enjoyment of Math for the male participants went up. This finding is consistent with the research of Lavin and Gordon, who found that far more boys than girls have strikingly positive attitudes toward computers, finding them more enjoyable, important, and friendly Lavin & Gordon, 1989).

Since both of these changes affected the experimental group, which had Internet access, it is possible that computer and Internet access had an influence on the changes in Anxiety toward Math and the Enjoyment of Math experienced by females. Students in the experimental group, as well as the control group, received their POW on a piece of paper. The experimental group then had Internet access to proceed further with these problems. The control group used normal classroom resources to investigate these problems. Perhaps receiving POW's randomly, which were not necessarily connected to the regular classroom curriculum being studied, seemed disjoint to the female population of the control group. The possibility also exists that student attitudes had been affected by the stress related to pressures associated with the end of the school year.

Based on the analysis of data related to Hypotheses 9 and 10 in Chapter 3 involving the effects of gender on the attitudes of participants in the control group, there was only one category in the MAI which changed during treatment. It was determined

before treatment that male students in the control group had a significantly higher Self-Concept about Math. However, after treatment, there was no significant difference in the attitudes of female students and male students in the control group regarding their Self-Concept about Math. It was observed that the Self-Concept about Math of students in the control group had improved during the course of the study. Since both the experimental and the control groups received and worked the Math Forum POW's for ten weeks, and since both the WK10AV and the problems on the McBride Problem Solving Test (PST) were directly correlated to concepts found in the ten POW's, it was concluded that female students had improved their self-concept by successfully participating in the study. The fact that female and male participants were equivalent in attitudes toward self-concept was consistent with the findings of Peterson, Burton, and Baker, who detected no significant difference between female and male students in their self-concept as geometry students (Peterson, Burton & Baker, 1983)

#### Relationship between "Time Spent" on Math Forum Archives and Problem-Solving Achievement on the WK10AV and PST

From analysis of data related to Hypothesis 13 it was concluded that irrespective of the amount of time spent on use of the Math Forum Archives there was no significant effect on the WK10AV of members of the experimental group. (Only the experimental group had access to the Math Forum Archives.) Since the amount of time allowed each week for working on the Math Forum POW was only twenty minutes, the researcher also concluded that this restriction limited time available each week for Archive use. If more

time had been made available to students for working on the POW each week, perhaps some of that additional time would have been spent utilizing the Math Forum Archives, and a corresponding effect might have been observed. In research conducted by Linda Wilson, she found that one type of activity that students responded negatively to was time pressure. Activities whose goal was to get the answer as quickly as possible are, for most students, extremely distasteful. Perhaps the limited amount of time available for solving the POW's affected students' use of the Archive resource (Wilson, 1995).

From analysis of Hypothesis 14, it was concluded that the amount of time of use of the Math Forum Archives did not have a significant effect on the PST score of members of the experimental group. (Only the experimental group had access to the Math Forum Archives.) Again, the limited time allowed for solution of the weekly POW could have affected the impact Archive use had on PST scores.

In summary, though the amount of time that the Math Forum Archives were used had no effect on either the WK10AV or the PST score, the small amount of classroom time available each week for solution of the current POW severely restricted the amount of time available for Archive use. The total time allowed for solution of the week's POW had an effect on the "Time on Task" available for Archive use.

#### Relationship between "Time Spent" on communication by Internet E-mail and Problem-Solving Achievement on the WK10AV and PST

From the analysis of data related to Hypotheses 15 and 16 in Chapter 3, it was seen that only seven out of fifty-three students in the experimental group ever communicated with others via Internet E-mail. There was insufficient data to determine

the effect that the amount of time spent communication with others via Internet E-mail had on participating student problem-solving achievement on theWK10AV and the PST.

#### McBride Problem Solving Test Achievement Results based on Treatment and Gender

From analysis of data related to Hypothesis 17, the analysis of variance with the PST as the dependent variable showed there was no significant difference in the problem-solving achievement of members of the experimental group and the control group after treatment as measured by the PST. When the EGST was used as a covariate, this too indicated there was no significant difference in the PST scores for the experimental and the control groups. Since the control group had achieved a significantly higher average than the experimental group on both their basic geometry achievement before treatment and WK10AV, it could be interpreted that statistically equivalent achievement on the PST by members of the experimental group represented a larger improvement in geometry problem-solving achievement than that demonstrated by the control group. However, in the analysis of the data using the EGST (prior knowledge) as the covariate and the PST as the dependent variable, the amount of increase on the PST shown by members of the experimental group for each point increase in the EGST score was almost the same as the amount of increase on the PST for each point increase on the EGST for the control group. In summary, for each point of increase on the EGST for participants in both the experimental group and the control group before treatment, there was a similar gain in the points scored on the PST. The appearance of an increase in achievement by members of the experimental group cannot be attributed to the treatment.

From analysis of data related to Hypothesis 18, the analysis of variance with the PST as the dependent variable showed no significant difference in the problem-solving achievement of female and male participants after treatment as measured by the PST. When the EGST was used as a covariate, this too indicated that there was no significant difference in the PST scores for female and male participants. This was consistent with the results in Table 17 which showed there was also no significant difference in achievement by female and male participants on both the EGST and the WK10AV. This was consistent with Frykholm's research which found that gender had little or nothing to do with a student's potential in geometry (Frykholm, 1994).

### Recommendations

#### Recommendations for Improved Use of Technology for Archive Utilization and Student Communication via the Internet

All three participating teachers and students from the experimental group received training in the use of the Internet to access both the Math Forum POW and the Archives. Solutions to each POW and the names and E-mail addresses of students who submitted correct answers to these problems were also listed in the Math Forum Archives in the weeks following their appearance. Students participating in this study were encouraged to utilize the solutions of previous geometry POW's available on the Math Forum Archives and communicate with other students via E-mail on the Internet to aid them in solving the current week's POW. Perhaps, due to the limited time available in a weekly high school geometry class for non-text oriented resources (twenty minutes in this study), students often did not have enough time to search the Math Forum Archives effectively or

communicate with others electronically on the solution of the current Week's POW. For future research concerning Archive use and electronic interaction with others, the researcher recommends that teachers designate more time for student access to the Internet to allow for communication and resource use. This could be during the class period or during the students' unscheduled class periods. Also, all students should receive training in the proper methods and protocol for E-mail use. One critical recommendation is that all students have access to their own E-mail addresses. An E-mail address is required for the students to submit their solutions for each week's POW to the Math Forum for analysis and for personal communication with others via Internet E-mail.

#### Recommendations for Improved Student Participation Questionnaire Design

Each week, students in the study were required to complete a Participating Student Questionnaire. Students in the experimental group were asked to rate the importance of the resources they used in the solution of each week's POW. Resources included (a) their teacher, (b) their classmates, (c) independent study, (d) e-mail, and (e) the Math Forum archives. This was originally designed to get feedback from students regarding their opinions on which resources seem to help them the most. However, when asked to rate each of the five resources listed, instead of rating the highest preference as the number 1, the second highest as the number 2 and so on, some students rated each resource on a scale from one to five. Therefore, some students gave different resources the same rating. For example, they rated both their teacher and their Classmates as a one.

A more clear explanation to students regarding the rating process for the resources used would help provide more useful feedback concerning student preference.

### Recommendations for Future Study

A recommendation for further study would be to give the POW's to students and allow the students to work on the POW for the entire week. This would allow more time for the students to work on their problem-solving skills, utilize the Math Forum Archives and communicate with others via Internet E-mail on the solution of the current Problem of the Week. Due to the fact that there is an abundance of resources available on the Internet to assist students in learning problem-solving skills, these resources could be a benefit to traditional high school students, non-traditional students seeking GED or college entrance skills and employees in the workforce. Further research is needed to examine the full host of benefits and problems associated with this kind of learning/teaching strategy. However, future investigations should allow for more and reasonable amounts of time for student use of electronic resources.

It was observed during this study that students needed Internet access, their own Internet addresses and the proper training to utilize Internet learning resources and E-mail communication. Future studies need to control for these factors so that all students have equal access and knowledge to use learning resources available electronically

There are high school geometry students who like challenges and have the time and technology available to utilize learning resources on the Internet. However, many students still do not have ready access to the Internet in either their schools or at home.

Future studies need to address the availability of Internet access both at school and at home.

Although there was no significant difference in the attitudes of female and male students in the experimental group regarding their Anxiety toward Math at the  $p \leq .05$  level before treatment, there was a significant difference at the  $p \leq .10$  level (ATM - 0.0593). Females scored higher than males in Anxiety toward Math at this level. Future studies need to investigate the issue of gender and anxiety toward mathematics when Internet and electronic instruction is involved.

In the analysis of covariance related to Hypothesis 13, with the WK10AV as the dependent variable and the time of use of the Math Forum Archives as a covariate, there was an Archive/Instructor Interaction of .0779. This does indicate that there could have been a relationship between the Instructor and improvement on the WK10AV for an increase in the amount of time spent on the Math Forum Archives. One of the three participating instructors experienced an increase in the WK10AV for an increase in the amount of time spent on the Math Forum Archives. The other two participating instructors experienced either no improvement or actually a decrease in the WK10AV for an increase in the amount of time spent on the Math Forum Archives. The researcher concludes that the instructor could be a factor in influencing beneficial use of the Math Forum Archives. The researcher recommends that future studies investigate the impact of the teacher on the effect that Archive use has on problem-solving achievement when Internet and electronic instruction is involved.

One recommendation for further study includes analysis of the effect that integration of the POW's into the regular classroom curriculum has on problem-solving achievement and attitudes toward mathematics. Within this integration, selection of problems which pertain to the concepts being taught daily in participating students' classrooms might have an effect not seen due to the open-ended problems used in this study.

An additional recommendation for further study involves the use of a questionnaire or personal interview at the end of the study to get views from students regarding their impressions of the effects of using technology in their mathematics classrooms. Questions could be asked to obtain student perceptions of the obstacles related to the use of E-mail and the Math Forum Archives. Additional questions could address the motivational factors regarding use of technology, and the views of students toward the use of enrichment activities which are not reflected in their grades for that class. Student perceptions of the relationship between their enrichment activities and the regular classroom curriculum could provide further insights into the reactions to the study. In addition, direct feedback of this sort might help researchers gain insight into the factors shaping student responses to experimental treatments and/or conditions.

### Recommendations for Practitioners

Recommendations for practitioners who plan to implement technological resources in their classrooms should include the integration of technology within their regular

curriculum, as opposed to using the resource as an “add-on” to complement their course work. Students will not use the Internet unless they are well-trained and comfortable with the technology, including E-mail and web browsers . Students must have convenient access to Internet resources both in-class and out-of-class, and the time necessary to properly use the technology.

It does not appear that interaction by students with technological resources produces a negative impact on either student achievement or attitudes toward mathematics. Teachers interested in implementing this type of change in their classes should seek out researchers and technical experts in the community to help them identify important resources and strategies to maximize their success in utilizing technology.

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**APPENDICES**

**APPENDIX A**

**University of Minnesota's Mathematics Attitude Inventory**

## NOTE TO USERS

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Appendix A  
102-104

UMI

MATHEMATICS ATTITUDE INVENTORYDirections

The following statements are about the study of mathematics. Please read each statement carefully and decide whether it describes the way you feel about mathematics. Then, find the number of the statement in the answer column (or on the answer sheet if one is provided), and blacken one of the spaces according to the following directions:

If you strongly agree with the statement, blacken space 1.

If you agree with the statement, blacken space 2.

If you disagree with the statement, blacken space 3.

If you strongly disagree with the statement, blacken space 4.

Be sure to blacken only one space for each statement.

Be sure to answer every question. You will have about 20 minutes to complete the 48 statements of the inventory. Remember to answer each statement according to the way you feel at the present time.

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	Strongly Agree	Agree	Disagree	Strongly Disagree
1. Mathematics is useful for the problems of everyday life.	0	0	0	0
2. Mathematics is something which I enjoy very much.	1	2	3	4
3. I like the easy mathematics problems best.	1	2	3	4
4. I don't do very well in mathematics.	1	2	3	4
5. My mathematics teacher shows little interest in the students.	1	2	3	4
6. Working mathematics problems is fun.	1	2	3	4
7. I feel at ease in a mathematics class.	1	2	3	4
8. I would like to do some outside reading in mathematics.	1	2	3	4
9. There is little need for mathematics in most jobs.	1	2	3	4
10. Mathematics is easy for me.	1	2	3	4
11. When I hear the word mathematics, I have a feeling of dislike.	1	2	3	4
12. Most people should study some mathematics.	1	2	3	4
13. I would like to spend less time in school doing mathematics.	1	2	3	4
14. Sometimes I read ahead in our mathematics book.	1	2	3	4
15. Mathematics is helpful in understanding today's world.	1	2	3	4
16. I usually understand what we are talking about in mathematics class.	1	2	3	4
17. My mathematics teacher makes mathematics interesting.	0	0	0	0
18. I don't like anything about mathematics.	1	2	3	4
19. No matter how hard I try, I cannot understand mathematics.	1	2	3	4
20. I feel tense when someone talks to me about mathematics.	1	2	3	4
21. My mathematics teacher presents material in a clear way.	1	2	3	4
22. I often think, "I can't do it," when a mathematics problem seems hard.	1	2	3	4
23. Mathematics is of great importance to a country's development.	1	2	3	4
24. It is important to know mathematics in order to get a good job.	1	2	3	4
25. It doesn't disturb me to work mathematics problems.	1	2	3	4

- |   | Strongly<br>Agree       | Agree                   | Disagree                | Strongly<br>Disagree    |
|---|-------------------------|-------------------------|-------------------------|-------------------------|
| 26. I would like a job which doesn't use any mathematics.   | <input type="radio"/> 1 | <input type="radio"/> 2 | <input type="radio"/> 3 | <input type="radio"/> 4 |
| 27. My mathematics teacher knows when we are having trouble with our work.                        | <input type="radio"/> 1 | <input type="radio"/> 2 | <input type="radio"/> 3 | <input type="radio"/> 4 |
| 28. I enjoy talking to other people about mathematics.  | <input type="radio"/> 1 | <input type="radio"/> 2 | <input type="radio"/> 3 | <input type="radio"/> 4 |
| 29. I like to play games that use numbers.  | <input type="radio"/> 1 | <input type="radio"/> 2 | <input type="radio"/> 3 | <input type="radio"/> 4 |
| 30. I am good at working mathematics problems.  | <input type="radio"/> 1 | <input type="radio"/> 2 | <input type="radio"/> 3 | <input type="radio"/> 4 |
| 31. My mathematics teacher doesn't seem to enjoy teaching mathematics.                            | <input type="radio"/> 1 | <input type="radio"/> 2 | <input type="radio"/> 3 | <input type="radio"/> 4 |
| 32. Sometimes I work more mathematics problems than are assigned in class.                        | <input type="radio"/> 1 | <input type="radio"/> 2 | <input type="radio"/> 3 | <input type="radio"/> 4 |
| 33. You can get along perfectly well in everyday life without mathematics.                        | <input type="radio"/> 1 | <input type="radio"/> 2 | <input type="radio"/> 3 | <input type="radio"/> 4 |
| 34. Working with numbers upsets me.   | <input type="radio"/> 1 | <input type="radio"/> 2 | <input type="radio"/> 3 | <input type="radio"/> 4 |
| 35. I remember most of the things I learn in mathematics.   | <input type="radio"/> 1 | <input type="radio"/> 2 | <input type="radio"/> 3 | <input type="radio"/> 4 |
| 36. It makes me nervous to even think about doing mathematics.                                    | <input type="radio"/> 1 | <input type="radio"/> 2 | <input type="radio"/> 3 | <input type="radio"/> 4 |
| 37. I would rather be given the right answer to a mathematics problem than to work it out myself. | <input type="radio"/> 1 | <input type="radio"/> 2 | <input type="radio"/> 3 | <input type="radio"/> 4 |
| 38. Most of the ideas in mathematics aren't very useful.  | <input type="radio"/> 1 | <input type="radio"/> 2 | <input type="radio"/> 3 | <input type="radio"/> 4 |
| 39. It scares me to have to take mathematics.   | <input type="radio"/> 1 | <input type="radio"/> 2 | <input type="radio"/> 3 | <input type="radio"/> 4 |
| 40. My mathematics teacher is willing to give us individual help.                                 | <input type="radio"/> 1 | <input type="radio"/> 2 | <input type="radio"/> 3 | <input type="radio"/> 4 |
| 41. The only reason I'm taking mathematics is because I have to.                                  | <input type="radio"/> 1 | <input type="radio"/> 2 | <input type="radio"/> 3 | <input type="radio"/> 4 |
| 42. It is important to me to understand the work I do in mathematics.                             | <input type="radio"/> 1 | <input type="radio"/> 2 | <input type="radio"/> 3 | <input type="radio"/> 4 |
| 43. I have a good feeling toward mathematics.   | <input type="radio"/> 1 | <input type="radio"/> 2 | <input type="radio"/> 3 | <input type="radio"/> 4 |
| 44. My mathematics teacher knows a lot about mathematics.   | <input type="radio"/> 1 | <input type="radio"/> 2 | <input type="radio"/> 3 | <input type="radio"/> 4 |
| 45. Mathematics is more of a game than it is hard work.   | <input type="radio"/> 1 | <input type="radio"/> 2 | <input type="radio"/> 3 | <input type="radio"/> 4 |
| 46. My mathematics teacher doesn't like students to ask questions.                                | <input type="radio"/> 1 | <input type="radio"/> 2 | <input type="radio"/> 3 | <input type="radio"/> 4 |
| 47. I have a real desire to learn mathematics.  | <input type="radio"/> 1 | <input type="radio"/> 2 | <input type="radio"/> 3 | <input type="radio"/> 4 |
| 48. If I don't see how to work a mathematics problem right away, I never get it.                  | <input type="radio"/> 1 | <input type="radio"/> 2 | <input type="radio"/> 3 | <input type="radio"/> 4 |

**APPENDIX B**

**Entering Geometry Student Test**

## NOTE TO USERS

Copyrighted materials in this document have not been filmed at the request of the author. They are available for consultation in the author's university library.

Appendix B  
106-108

UMI

## ENTERING GEOMETRY STUDENT TEST

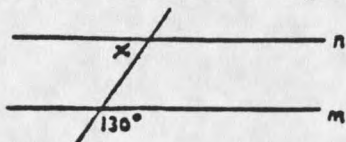
1. Perpendicular lines
    - (a) intersect to form four right angles
    - (b) intersect to form two acute and two obtuse angles
    - (c) do not intersect at all
    - (d) intersect to form four acute angles
    - (e) none of the above
  2. The area of a rectangle with length 3 inches and width 12 inches is
    - (a) 18 sq in
    - (b) 72 sq in
    - (c) 36 sq in
    - (d) 15 sq in
    - (e) 30 sq in
  3. If two figures are similar but not congruent then they
    - (a) have congruent bases and congruent altitudes
    - (b) have the same height
    - (c) both have horizontal bases
    - (d) have a different shape but the same size
    - (e) have a different size but the same shape
  4. The measure of an obtuse angle is
    - (a)  $90^\circ$
    - (b) between  $45^\circ$  and  $90^\circ$
    - (c) less than  $90^\circ$
    - (d) between  $90^\circ$  and  $180^\circ$
    - (e) more than  $180^\circ$
  5. At right, A, B, and D lie on a straight line. The measure of angle ABC is
    - (a)  $120^\circ$
    - (b)  $60^\circ$
    - (c)  $80^\circ$
    - (d)  $140^\circ$
    - (e) need more information
- 
6. Parallel lines are lines
    - (a) in the same plane which never meet
    - (b) which never lie in the same plane and never meet
    - (c) which always form angles of  $90^\circ$  when they meet
    - (d) which have the same length
    - (e) none of the above
  7. If O is the center of the circle, segment  $\overline{OA}$  is called a
    - (a) radius of the circle
    - (b) diameter of the circle
    - (c) chord of the circle
    - (d) segment of the circle
    - (e) sector of the circle
- 
8. Angles 1 and 2 are called
    - (a) opposite angles
    - (b) parallel angles
    - (c) alternate interior angles
    - (d) alternate exterior angles
    - (e) corresponding angles
-

9. The measure of a right angle is

- (a) less than  $90^\circ$
- (b) between  $90^\circ$  and  $180^\circ$
- (c)  $45^\circ$
- (d)  $90^\circ$
- (e)  $180^\circ$

10. Lines  $n$  and  $m$  are parallel. The measure of angle  $x$  is

- (a)  $65^\circ$
- (b)  $130^\circ$
- (c)  $30^\circ$
- (d)  $40^\circ$
- (e)  $50^\circ$

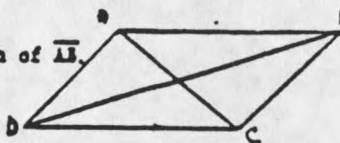


11. An equilateral triangle has

- (a) all three sides the same length
- (b) one obtuse angle
- (c) two angles having the same measure and the third a different measure
- (d) all three sides of different lengths
- (e) all three angles of different measures

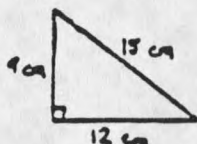
12. Given that ABCD is a parallelogram, which of the following statements is true?

- (a) ABCD is equiangular
- (b) Triangle AED is congruent to triangle CDB.
- (c) The perimeter of ABCD is four times the length of  $\overline{AE}$ .
- (d)  $\overline{AC}$  is the same length as  $\overline{BD}$ .
- (e) All of the above are true.



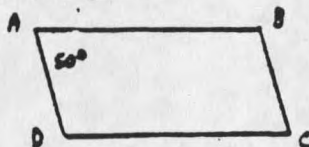
13. The area of the triangle shown is

- (a) 36 sq cm
- (b) 54 sq cm
- (c) 72 sq cm
- (d) 108 sq cm
- (e) 1620 sq cm



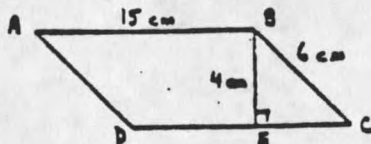
14. ABCD is a parallelogram. The measure of angle C is.

- (a)  $40^\circ$
- (b)  $130^\circ$
- (c)  $140^\circ$
- (d)  $50^\circ$
- (e) need more information



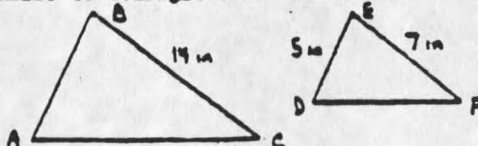
15. The perimeter of this parallelogram ABCD is

- (a) 25 cm
- (b) 42 cm
- (c) 21 cm
- (d) 60 cm
- (e) 90 cm



16. Triangle ABC is similar to triangle DEF. The measure of  $\overline{AB}$  is

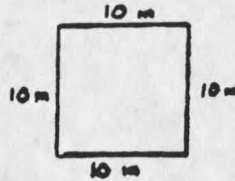
- (a) 10 in
- (b) 11 in
- (c) 12 in
- (d) 13 in
- (e) 15 in



17. The plane figure produced by drawing all points exactly 6 inches from a given point is a
- circle with a diameter of 6 inches
  - square with a side of 6 inches
  - sphere with a diameter of 6 inches
  - cylinder 6 inches high and 6 inches wide
  - circle with a radius of 6 inches

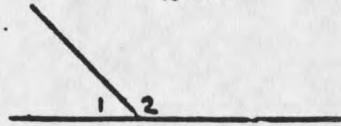
18. The area of the square shown is

- 20 sq in
- 40 sq in
- 40 inches
- 100 sq in
- 100 inches



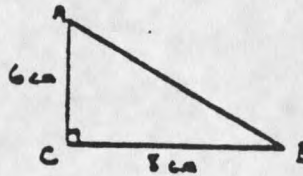
19. Angles 1 and 2 are

- interior
- vertical
- supplementary
- complementary
- scalene



20. Angle C is a right angle. The length of side  $\overline{AB}$  is

- 8 cm
- 14 cm
- 10 cm
- 12 cm
- 18 cm



**APPENDIX C**

**Student Participation Questionnaires**

### Student Participation Questionnaire

Name \_\_\_\_\_

Problem for the Week of \_\_\_\_\_

Your Solution:

Experimental Group

#### Student Activity Log

1. Estimate total minutes spent in class
___ Working alone
___ Working with your teacher
___ Working with your classmates
___ Using email
___ Using the POW archives
<u>20</u> Total minutes spent in class
2. Rank the following according to their usefulness in solving this week's POW? [1 = most useful, 5 = least useful]
___ Working alone
___ Working with your teacher
___ Working with your classmates
___ Using email
___ Using the POW archives
3. In the past week, did you continue your POW problem solving activities outside of class by working alone or with others?
___ Yes
___ No
4. In the past week, did you continue your POW problem solving activities outside of class by using Math Forum Internet resources?
___ Yes
___ No

#### Performance Rating (Teacher Only)

- Complete, Accurate Solution
- Partial Solution, Mostly
- Partial Solution, Slightly
- Invalid or No Solution

### Student Participation Questionnaire

Name \_\_\_\_\_

Problem for the Week of \_\_\_\_\_

**Your Solution:**

**Control Group**

**Student Activity Log**

1. Estimate total minutes spent in class

- Working alone
- Working with your teacher
- Working with your classmates

20 Total minutes spent in class

2. Rank the following according to their usefulness in solving this week's POW?  
[1 = most useful, 3 = least useful]

- Working alone
- Working with your teacher
- Working with your classmates

3. In the past week, did you continue your POW problem solving activities outside of class by working alone or with others?

- Yes
- No

**Performance Rating (Teacher Only)**

- Complete, Accurate Solution
- Partial Solution, Mostly
- Partial Solution, Slightly
- Invalid or No Solution

**APPENDIX D**

**Swarthmore College's Math Forum Research Participation with MSU-Bozeman**

**APPENDIX D****Swarthmore College's Math Forum Research Participation with MSU-Bozeman**

This study could not have not have been possible without the willing participation by key members of Swarthmore College's Math Forum. Students from twelve countries and 27 states in the United States were successful in solving and submitting solutions to the ten Problems of the Week co-written by Annie Fetter of Swarthmore College and the researcher in this study from MSU-Bozeman.

Dr. Gene Klotz, Director of the Math Forum, an NSF funded program, was helpful from the beginning of the study and was willing to allow me to work with the Math Forum's Problem of the Week author Annie Fetter in the development and construction of problems suitable for the study.

The researcher also had the opportunity to communicate electronically with Ann Renninger, Evaluator at the Math Forum, regarding the reason and need for the study. This presented an excellent opportunity for collaboration between colleges in a research project.

Annie Fetter was at the heart of this study from its inception. Her dedication to the students who submitted correct solutions and her genuine interest in their mathematics learning careers has been an inspiration.

**APPENDIX E**

**Ten POW's with Weekly Scoring Rubrics**

## APPENDIX E

### Ten POW's with Weekly Scoring Rubrics

#### 1) PROBLEM OF THE WEEK FOR - March 16 -20, 1998 ("POW" 1)

I was at the building supply store the other day and these two people were having an argument. I think they were going to build an enclosure for their dog (I hope it's a small dog!). The guy was leaning against 3 sections of fencing that were 6, 8, and 12 feet long. The woman was telling him to get rid of the 12 foot section and buy a 10 footer - they would save money, and would be able to fence in a bigger area.. He didn't seem to believe her. What do you think? Go with the 10 footer or the 12 footer? Make sure you tell me why - I want to be able to explain it to them if I ever see them again.

#### RUBRIC FOR ASSESSING POW # 1

##### Score - 3 Complete accurate solution - All

The student has used all markings, notations, terminology, theorems and definitions correctly, has correctly met the problem objective, and all required calculations have been performed correctly.

1. The student recognizes that the 6', 8' and 10' foot sections form a right triangle, with the 6' and 8' sections as legs.
2. The student recognizes that the 6', 8', and 12' foot sections form an obtuse triangle.
3. The student recognizes that the area of the right triangle is greater than the area of the obtuse triangle.
4. If areas for both figures have been calculated by using the lengths of the sides, this is also a valid solution.

##### Score - 2 Partial solution - Mostly

The student has used the given or known facts consistently throughout the problem, has recognized the problem objective, and makes use of pertinent theorems and definitions, but has trivial mistakes or irrelevant statements which lead to an incorrect solution.

1. The student recognizes that the 6', 8' and 10' foot sections form a right triangle, with the 6' and 8' sections as legs.
2. The student recognizes that the 6', 8', and 12' foot sections form an obtuse triangle.

##### Score - 1 Partial solution - (Slightly)

The student appears to have a plan and utilizes at least one of the givens or other knowns in the problem, but he or she has not completed enough of the problem to determine if their direction taken would end in a correct solution.

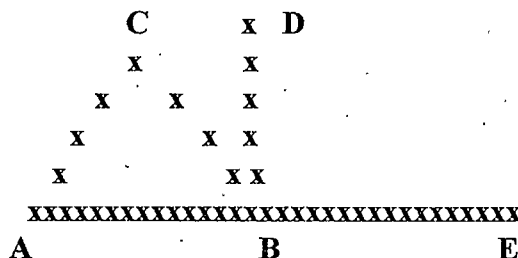
1. The student recognizes that the 6', 8' and 10' foot sections form a right triangle, with the 6' and 8' sections as legs.

**Score - 0 Invalid response - (Definitely Not)**

The student has used markings, notations terminology theorems and definitions incorrectly or inappropriately in the solution, and the correct objective has not been recognized.

**2) PROBLEM OF THE WEEK FOR - March 23 - 27, 1998 ("POW" 2)**

Here is a good little puzzle for you. Make sure you give me a good explanation of why you know the answer is right. Take a look at the following figure:  $AC = BC$ , angle  $ACB$  is twice the measure of angle  $CBD$ , and angle  $DBE = 90$  degrees. What is angle  $CBD$ ?



**RUBRIC FOR ASSESSING POW # 2**

**Score - 3 Complete accurate solution - All**

The student has used all markings, notations, terminology, theorems and definitions correctly, has correctly met the problem objective, and all required calculations have been performed correctly.

- 1) The student recognizes that angle  $CAB$  is congruent to angle  $ABC$ ,
- 2) The student recognizes that angle  $ABC$  is equal to  $(90 - X)$ ,
- 3) The student recognizes that angle  $ACB$ :  $(2X)$  plus angle  $CAB$   $(90 - X)$  plus angle  $ABC$   $(90 - X)$  equals 180 degrees, and
- 4) The student recognizes that any value for  $X$  will make the relationship true.

**Score - 2 Partial solution - Mostly**

The student has used the given or known facts consistently throughout the problem, has recognized the problem objective, and makes use of pertinent theorems and definitions, but has trivial mistakes or irrelevant statements which lead to an incorrect solution.

1) The student recognizes that angle CAB is congruent to angle ABC, 2) The student recognizes that angle ABC is equal to  $90 - X$ , and 3) The student recognizes that angle ACB ( $2X$ ) plus angle CAB ( $90 - X$ ) plus angle ABC ( $90 - X$ ) equals 180 degrees.

**Score - 1      Partial solution - (Slightly)**

The student appears to have a plan and utilizes at least one of the givens or other knowns in the problem, but he or she has not completed enough of the problem to determine if their direction taken would end in a correct solution.

1) The student recognizes that angle CAB is congruent to angle ABC, since base angles of isosceles triangles are congruent, or 2) The student recognizes that angle ABC is equal to  $90 - X$

**Score - 0      Invalid response - (Definitely Not)**

The student has used markings, notations terminology theorems and definitions incorrectly or inappropriately throughout the solution, and the correct objective has not been recognized.

3)      **PROBLEM OF THE WEEK FOR - March 30 - April 3, 1998 ("POW" 3)**

I have enjoyed reading your solutions to my shotgun target problems, so I have another one for you.

I am constructing another target for long range shooting. The target will have a six inch diameter black bull's eye, and concentric circles with diameters of 12", 18", and 24" respectively, to form alternating white and black bands. There is also a 24" square circumscribed about the outermost circle. Got it? Okay.

What is the area of the bull's eye and what is the area of each of the white and black bands making up the target? (There are four areas to determine - the bull, two white bands, and one black band.)

While we're at it, what's the area between the 24" outer circle and the 24" square?

**What do you notice about the relationship between the area of each section and the band just outside it?**

**EXTRA:** Now that you're warmed up, can you identify **WHY** the relationship in the last question exists? (You might want to try some similar setups with targets of different sizes to see if that helps.)

### **RUBRIC FOR ASSESSING POW # 3**

#### **Score - 3      Complete accurate solution - All**

**The student has used all markings, notations, terminology, theorems and definitions correctly, has correctly met the problem objective, and all required calculations have been performed correctly.**

1) The student determines the area of the bulls-eye to be  $9\pi$  square inches, 2) the areas of the respective white and black bands to be  $27\pi$ ,  $45\pi$ , and  $63\pi$  square inches, and 3) The area between the 24" outer circle and the 24" square to be  $(476 - 144\pi)$  square inches. The relationship is that each band is  $18\pi$  square inches larger in area than the preceding band.

Extra: The area of each band is twice the area of the bulls-eye larger than the area of the preceding ring.

#### **Score - 2      Partial solution - Mostly**

**The student has used the given or known facts consistently throughout the problem, has recognized the problem objective, and makes use of pertinent theorems and definitions, but has trivial mistakes or irrelevant statements which lead to an incorrect solution.**

1) The student determines the area of the bulls-eye to be  $9\pi$  square inches, 2) the areas of the respective white and black bands to be  $27\pi$ ,  $45\pi$ , and  $63\pi$  square inches.

#### **Score - 1      Partial solution - (Slightly)**

**The student appears to have a plan and utilizes at least one of the givens or other knowns in the problem, but he or she has not completed enough of the problem to determine if their direction taken would end in a correct solution.**

1) The student calculates the area of the bulls-eye to be  $9\pi$  square inches.

#### **Score - 0      Invalid response - (Definitely Not)**

The student has used markings, notations terminology theorems and definitions incorrectly or inappropriately throughout the solution, and the correct objective has not been recognized.

**4) PROBLEM OF THE WEEK FOR - April 6 - 10, 1998 ("POW" 4)**

I am putting a new garden in part of my yard. I already have rectangular gardens, square gardens, and a semi-circular garden. So I figure I need a trapezoidal garden. I am trying to figure out the dimensions of one part of it, so let me give you the problem. Make sure you read carefully and draw a good figure!

Call the garden plot ABCD with sides AB and CD parallel. Point E is on AD and F is on BC, with EF parallel to AB. The distance from A to E is  $\frac{3}{4}$  of the distance from E to D. If segment BC is 14 feet long, how long is segment FC?

**RUBRIC FOR ASSESSING POW # 4**

**Score - 3 Complete accurate solution - All**

The student has used all markings, notations, terminology, theorems and definitions correctly, has correctly met the problem objective, and all required calculations have been performed correctly.

1) The student recognizes that there are proportional relationships between the lengths of segments in the nonparallel sides of the trapezoid.  $AE/AD = BF/FC$  or  $DE/AD = FC/BC$ , 2) The student writes a proportion showing that  $DE/AD = FC/14$ . (Set up the proportion **X is to  $\frac{7}{4}$  X as the length of FC is to 14**), and 3) The student solves the proportion and obtains 8 feet for the length of segment FC.

**Score - 2 Partial solution - Mostly**

The student has used the given or known facts consistently throughout the problem, has recognized the problem objective, and makes use of pertinent theorems and definitions, but has trivial mistakes or irrelevant statements which lead to an incorrect solution.

1) The student recognizes that there are proportional relationships between the lengths of segments in the nonparallel sides of the trapezoid.  $AE/AD = BF/FC$  or  $DE/AD = FC/BC$ , and 2) The student writes a proportion showing that  $DE/AD = FC/14$ . (Set up the proportion **X is to  $\frac{7}{4}$  X as the length of FC is to 14**)

**Score - 1      Partial solution - (Slightly)**

The student appears to have a plan and utilizes at least one of the givens or other knowns in the problem, but he or she has not completed enough of the problem to determine if their direction taken would end in a correct solution.

1) The student recognizes that there are proportional relationships between the lengths of segments in the nonparallel sides of the trapezoid.  $AE/AD = BF/FC$  or  $DE/AD = FC/BC$   
**Note: Parallel lines in a plane subtend proportional segments on transversals which intersect these given parallel lines**

**Score - 0      Invalid response - (Definitely Not)**

The student has used markings, notations terminology theorems and definitions incorrectly or inappropriately throughout the solution, and the correct objective has not been recognized.

**5)      PROBLEM OF THE WEEK FOR - April 13 - 17, 1998 ("POW" 5)**

I think I am finally going to build a shed for my motorcycle. I've got six posts that are six inches square and ten feet long. The plan is to dig holes one foot in diameter and two feet deep in which to bury the posts so that the top of the posts will be eight feet above the ground. The shed will get built on that framework.

Now, here's the part I need help with. I have to know how many bags of concrete to buy, so I need to know how many cubic feet of concrete I will need to fill the six holes with concrete after I have put the posts in. Cubic feet is tough - think carefully about that part!

**RUBRIC FOR ASSESSING POW # 5****Score - 3      Complete accurate solution - All**

The student has used all markings, notations, terminology, theorems and definitions correctly, has correctly met the problem objective, and all required calculations have been performed correctly.

1) The student is able to calculate the volume of the buried portion of the posts and the volume of the holes in cubic feet 2) The student is also able to calculate the volume of concrete needed by subtracting the volume of the buried portion of the posts from the volume of the holes, 3) The volume of the buried portion of the poles can be calculated by multiplying (6/12 feet) times (6/12 feet) times (2 feet) for a volume of .50 cubic feet

times 6 poles for a total of 3 cubic feet , and 4) The volume of each hole would be approximately  $3.14 (\pi)$  times  $[(6/12) \text{ squared}]$  times 2 feet for a volume of approximately 1.57 cubic feet times six holes equals approximately 9.42 cubic feet. Subtracting 3 cu. Ft. from 9.42 cu. Ft. yields 6.42 cu. Ft.

**Score - 2      Partial solution - Mostly**

**The student has used the given or known facts consistently throughout the problem, has recognized the problem objective, and makes use of pertinent theorems and definitions, but has trivial mistakes or irrelevant statements which lead to an incorrect solution.**

1) The student is able to calculate the volume of the buried portion of the posts and the volume of the holes in cubic inches, and 2) The student is also able to calculate the volume of concrete needed by subtracting the volume of the buried portion of the posts from the volume of the holes with a resulting answer in cubic inches.

**Score - 1      Partial solution - (Slightly)**

**The student appears to have a plan and utilizes at least one of the givens or other knowns in the problem, but he or she has not completed enough of the problem to determine if their direction taken would end in a correct solution.**

1) The student is only able to calculate the volume of the buried portion of the posts or the volume of the holes in cubic inches, or in cubic feet.

**Score - 0      Invalid response - (Definitely Not)**

**The student has used markings, notations terminology theorems and definitions incorrectly or inappropriately throughout the solution, and the correct objective has not been recognized.**

**6)      PROBLEM OF THE WEEK FOR - April 20 - 24, 1998 ("POW" 6)**

**Here's a puzzle for you. Read carefully and draw a good picture. Remember that you MUST explain how you got the answer and you must convince me you are right!**

**Lost Lake Road lies 300 feet North of Vanda's house and runs straight East and West. Art lives 600 feet South of Lost Lake Road and 1200 feet down the road from Vanda. Neither Art nor Vanda have a phone. Art's carrier pigeon just arrived at Vanda's screeching loudly with an emergency message from Art. He has fallen and**

broken his leg at home. Vanda decided to ride her dirt bike from her home to Lost Lake Road to try to flag down a passing motorist with a cell phone so that an ambulance can be sent to pick up Art. Vanda wants to ride in a straight line to Lost Lake Road, and then go straight from that point to Art's house. Where must Vanda hit Lost Lake Road (in the 1200 foot stretch) to make the distance she traveled the shortest?

### RUBRIC FOR ASSESSING POW # 6

**Score - 3      Complete accurate solution - All**

**The student has used all markings, notations, terminology, theorems and definitions correctly, has correctly met the problem objective, and all required calculations have been performed correctly.**

1) The student draws a sketch of the problem correctly, using the "Givens" in the problem, 2) The student draws a segment 600' Due North from Vanda's house (300' to Lost Lake Road, and 300 feet further, Due North), 3) The student then draws a segment connecting the endpoint of this segment (the endpoint which lies north of Lost Lake Road) to Art's house, 4) The student recognizes that similar triangles are formed and assigns a variable ( $x$ ) to one portion of the 1200' segment on Lost Lake Road (the segment between the points where the two drawn segments intersected Lost Lake Road), and  $(1200 - x)$  for the remainder of the 1200' segment, and 5) The student sets up the proportion  $300/x = 600/(1200-x)$ , solves this, and gets distances of 400' and 800' respectively. Therefore, if Vanda rides her dirt bike to the point 400' East along Lost Lake Road from the point where the northward segment drawn from her house intersected Lost Lake Road and the rode straight from there to Art's house, she would have traveled the shortest distance.

**Score - 2      Partial solution - Mostly**

**The student has used the given or known facts consistently throughout the problem, has recognized the problem objective, and makes use of pertinent theorems and definitions, but has trivial mistakes or irrelevant statements which lead to an incorrect solution.**

1) The student draws a sketch of the problem correctly, using the "Givens" in the problem, 2) The student draws a segment 600' Due North from Vanda's house (300' to Lost Lake Road, and 300 feet further, Due North), 3) The student then draws a segment connecting the endpoint of this segment (the endpoint which lies north of Lost Lake Road) to Art's house, and 4) The student recognizes that similar triangles are formed.

**Score - 1      Partial solution - (Slightly)**

The student appears to have a plan and utilizes at least one of the givens or other knowns in the problem, but he or she has not completed enough of the problem to determine if their direction taken would end in a correct solution.

The student draws a sketch of the problem correctly, using the "Givens" in the problem.

**Score - 0 Invalid response - (Definitely Not)**

The student has used markings, notations terminology theorems and definitions incorrectly or inappropriately in the solution, and the correct objective hasn't been recognized.

**7) PROBLEM OF THE WEEK FOR - April 27 - May 1, 1998 ("POW" 7)**

Given triangle ABC, with AB perpendicular to BC, points E and G on AB and points D and F on AC such that AB is perpendicular to DE and FG, and that  $AE=EG=GB$ . Does  $AD=DF=FC$ ? You need to solve this problem without using the Triangle Proportionality Theorem? (It's called other things as well, but the basic idea is that if a line is parallel to one side of a triangle and intersects the other two sides, then it divides the two sides proportionally.) No credit for using the theorem, and make sure that you explain your answer thoroughly.

**RUBRIC FOR ASSESSING POW # 7**

**Score - 3 Complete accurate solution - All**

The student has used all markings, notations, terminology, theorems and definitions correctly, has correctly met the problem objective, and all required calculations have been performed correctly.

1) The student draws triangle ABC, positions points D,E,F,G, and draws segments DE and FG correctly, 2) The student also labels the right angles, 3) The student draws a segment from point D perpendicular to side BC and labels this point H (Any letter selected by the student is acceptable), and a segment from point F perpendicular to side BC. Label the point where this segment intersects side BC as I, 4) The student labels the point where segments DH and FG intersect as J, 5) Since segments AB, DH, and FI are all perpendicular to BC, segments AB, DH, and FI are all parallel, 6) The student recognizes that angles EAD, HDF, and IFC are corresponding angles when side AC is considered the transversal and segments AB, DH, and FI are parallel. Consequently these angles are congruent, 7) Segment EG is congruent to DJ, and FI is congruent to GB since they are on opposite sides of the rectangles formed in the original construction, 8) The right angles formed in the construction also made angles AED, DJF, and FIC congruent, 9) The student recognizes that triangles AED, DJF, and FIC are congruent

and 10) The student recognizes that segments AD, DF, and FC are equal since they are corresponding parts of congruent triangles.

**Score - 2      Partial solution - Mostly**

**The student has used the given or known facts consistently throughout the problem, has recognized the problem objective, and makes use of pertinent theorems and definitions, but has trivial mistakes or irrelevant statements which lead to an incorrect solution.**

1) The student draws triangle ABC, positions points D,E,F,G, and draws segments DE and FG correctly, 2) The student also labels the right angles, and 3) The student draws a segment from point D perpendicular to side BC and labels this point H (Any letter selected by the student is acceptable), and a segment from point F perpendicular to side BC. Label the point where this segment intersects side BC as I.

**Score - 1      Partial solution - (Slightly)**

**The student appears to have a plan and utilizes at least one of the givens or other knowns in the problem, but he or she has not completed enough of the problem to determine if their direction taken would end in a correct solution.**

The student draws triangle ABC, positions points D,E,F,G, and draws segments DE and FG correctly.

**Score - 0      Invalid response - (Definitely Not)**

**The student has used markings, notations terminology theorems and definitions incorrectly or inappropriately throughout the solution, and the correct objective has not been recognized.**

**8)      PROBLEM OF THE WEEK FOR - May 4 - 8, 1998 ("POW" 8)**

Here's a little more work with triangles for you. Using the diagram, show that

$$\frac{X}{1-X} = \frac{1}{X} \quad \text{Angle SPQ is 36 degrees, and angle SRQ is 72 degrees}$$

**RUBRIC FOR ASSESSING POW # 8**

**Score - 3      Complete accurate solution - All**

**The student has used all markings, notations, terminology, theorems and definitions correctly, has correctly met the problem objective, and all required calculations have been performed correctly.**

1) The student recognizes that angle  $SQR = 72$  degrees since angles  $SRQ$  and  $SQR$  are base angles of isosceles triangle  $QSR$  and are therefore congruent, 2) From the information provided on (1), the student determines that angle  $QSR$  equals 36 degrees, since the sum of the interior angles of a triangle is 180 degrees, 3) Therefore, Triangle  $QSR$  is isosceles and has base angles of 72 degrees and a vertex angle of 36 degrees, 4) The student recognizes that angle  $PSQ$  equals 36 degrees, since angles  $SPQ$  and  $PSQ$  are base angles of isosceles triangle  $PQS$  and are therefore congruent, 5) The student recognizes that angle  $PSR$  equals 72 degrees [ (Angle  $PSQ$  (36 degrees) plus angle  $QSR$  (36 degrees) equals angle  $PSR$  (72 degrees)], 6) Therefore angle  $PSR$  equals angle  $SRQ$ , 7) The student recognizes that triangle  $PRS$  is an isosceles triangle with base angles of 72 degrees and a vertex angle of 36 degrees, 8) Therefore,  $PS$  equals  $PR$  equals 1, since the sides opposite equal angle in a triangle are equal, 9) The student recognizes that since  $PR$  equals 1, and  $PQ$  equals  $(X)$ , then  $QR$  equals  $(1 - X)$ , 10) Triangle  $PRS$  is similar to triangle  $QSR$ , since their respective angles are congruent, and 11) The student recognizes that the ratio of the length of side  $SR$  ( $X$ ) to the length of the base  $(1 - X)$  in triangle  $QSR$  is equal to the ratio of the length of side  $PS$  (1) to the length of the base  $RS$  ( $X$ ) in triangle  $PRS$ , so  $x/(1-x) = 1/x$ .

**Score - 2      Partial solution - Mostly**

**The student has used the given or known facts consistently throughout the problem, has recognized the problem objective, and makes use of pertinent theorems and definitions, but has trivial mistakes or irrelevant statements which lead to an incorrect solution.**

1) The student recognizes that angle  $SQR = 72$  degrees since angles  $SRQ$  and  $SQR$  are base angles of isosceles triangle  $QSR$  and are therefore congruent, 2) From the information provided on (1), the student determines that angle  $QSR$  equals 36 degrees, since the sum of the interior angles of a triangle is 180 degrees, 3) Therefore, Triangle  $QSR$  is isosceles and has base angles of 72 degrees and a vertex angle of 36 degrees, 4) The student recognizes that angle  $PSQ$  equals 36 degrees, since angles  $SPQ$  and  $PSQ$  are base angles of isosceles triangle  $PQS$  and are therefore congruent, 5) The student recognizes that angle  $PSR$  equals 72 degrees [ (Angle  $PSQ$  (36 degrees) plus angle  $QSR$  (36 degrees) equals angle  $PSR$  (72 degrees)], 6) Therefore angle  $PSR$  equals angle  $SRQ$ , and 7) The student recognizes that triangle  $PRS$  is an isosceles triangle with base angles of 72 degrees and a vertex angle of 36 degrees.

**Score - 1      Partial solution - (Slightly)**

**The student appears to have a plan and utilizes at least one of the givens or other knowns in the problem, but he or she has not completed enough of the problem to determine if their direction taken would end in a correct solution.**

1) The student recognizes that angle  $SQR = 72$  degrees since angles  $SRQ$  and  $SQR$  are base angles of isosceles triangle  $QSR$  and are therefore congruent, 2) From the information provided on (1), the student determines that angle  $QSR$  equals 36 degrees, since the sum of the interior angles of a triangle is 180 degrees, and 3) Therefore, Triangle  $QSR$  is isosceles and has base angles of 72 degrees and a vertex angle of 36 degrees.

**Score - 0 Invalid response - (Definitely Not)**

**The student has used markings, notations terminology theorems and definitions incorrectly or inappropriately throughout the solution, and the correct objective has not been recognized.**

**9) PROBLEM OF THE WEEK FOR - May 11 - 15, 1998 ("POW" 9)**

**You did pretty well last week explaining that problem! This week you need to find the answer AND explain why. Look at the picture below.  $ABE$ ,  $BFE$ , and  $DBC$  are right triangles (with the right angles at  $B$  and  $F$ ). What can I put in for  $x$ ,  $y$ , and  $z$  so that the picture will work? Also, what's the area of quadrilateral  $ABFE$ ?**

**RUBRIC FOR ASSESSING POW # 9**

**Score - 3 Complete accurate solution - All**

**The student has used all markings, notations, terminology, theorems and definitions correctly, has correctly met the problem objective, and all required calculations have been performed correctly.**

1) Given that  $BC = 8$ , and that  $DC = 10$ , the student uses the Pythagorean Theorem to ascertain that  $BD = 6$ , 2) Since  $DE = 1$ , the student then subtracts 1 from  $BD$  (6) to find that  $BE = 5$  ( $X=5$ ), 3) Using  $AB = 12$ , and  $BE = 5$ , the student uses the Pythagorean Theorem to determine that  $AE = 13$  ( $Y=13$ ), 4) Using  $BE = 5$ , and  $FE = 4$ , the student uses the Pythagorean Theorem to calculate  $FB = 3$  ( $Z=3$ ), 5) The student recognizes that the area of triangle  $ABE$  equals one-half times twelve times five, or 30 square units. The area of triangle  $EFB$  equals one-half times three times four, or 6 square units, and 6) The student concludes by showing that the area of triangle  $ABE$  minus the area of triangle

EFB equals the area of quadrilateral ABFE, so the area of quadrilateral ABFE equals 30 square inches minus 6 square inches for a result of 24 square inches.

**Score - 2      Partial solution - Mostly**

**The student has used the given or known facts consistently throughout the problem, has recognized the problem objective, and makes use of pertinent theorems and definitions, but has trivial mistakes or irrelevant statements which lead to an incorrect solution.**

1) Given that  $BC = 8$ , and that  $DC = 10$ , the student uses the Pythagorean Theorem to ascertain that  $BD = 6$ , 2) Since  $DE = 1$ , the student then subtracts 1 from  $BD$  (6) to find that  $BE = 5$  ( $X=5$ ), and 3) Using  $AB = 12$ , and  $BE = 5$ , the student uses the Pythagorean Theorem to determine that  $AE = 13$  ( $Y=13$ ).

**Score - 1      Partial solution - (Slightly)**

**The student appears to have a plan and utilizes at least one of the givens or other knowns in the problem, but he or she has not completed enough of the problem to determine if their direction taken would end in a correct solution.**

1) Given that  $BC = 8$ , and that  $DC = 10$ , the student uses the Pythagorean Theorem to ascertain that  $BD = 6$ , and 2) Since  $DE = 1$ , the student then subtracts 1 from  $BD$  (6) to find that  $BE = 5$ .

**Score - 0      Invalid response - (Definitely Not)**

**The student has used markings, notations terminology theorems and definitions incorrectly or inappropriately throughout the solution, and the correct objective has not been recognized.**

#### **10)      PROBLEM OF THE WEEK FOR - May 18 - 22, 1998 ("POW" 10)**

**I was looking at a picture of a platform that you could use for hunting. They didn't include all the dimensions, but they do include some odd information! You can help me figure out the other dimensions.**

**This platform is 3 feet in diameter and centered on top of a metal pole. The ladder leans against the outer edge of the platform. When you have climbed 5 feet up the ladder, you are 4 feet above the ground. When you are 10 feet up the ladder, you are 8 feet above the ground. And, when you reach the top of the ladder, you're 16 feet off the ground.**

**How long is the ladder? How far is the base of the ladder from the center of the metal pole?**

**Make sure you explain each part you figure out!**

### **RUBRIC FOR ASSESSING POW # 10**

#### **Score - 3 Complete accurate solution - All**

**The student has used all markings, notations, terminology, theorems and definitions correctly, has correctly met the problem objective, and all required calculations have been performed correctly.**

1) The student recognizes that there are 2 right triangles formed by using the "lengths of the ladder" as a hypotenuse and the "height above ground" as the altitudes. [These are (3,4,5) and (6,8,10) right triangles], 2) The student recognizes that the triangle formed by the 16 foot high pole, the ground, and the entire length of the ladder is similar to the 2 triangles in step # 1, 3) By setting up the proportion: 4 feet (height) is to 5 feet (hypotenuse) as 16 feet (height) is to "L" feet (hypotenuse),  $4/5 = 16/L$ ,  $L = 20$  feet, the length of the ladder, 4) With 20 feet as a hypotenuse, and 16 feet as a height, the distance from the base of the ladder to a point directly below the edge of the platform is calculated to be 12 feet, and 5) By dividing the diameter of the platform (3 feet) by 2, the student recognizes that the distance from the top of the ladder to the pole to be 1.5 feet. When this is added to the 12 feet calculated in step # 4, the distance from the base of the ladder to the center of the pole is calculated to be 13.5 feet.

#### **Score - 2 Partial solution - Mostly**

**The student has used the given or known facts consistently throughout the problem, has recognized the problem objective, and makes use of pertinent theorems and definitions, but has trivial mistakes or irrelevant statements which lead to an incorrect solution.**

1) The student recognizes that there are 2 right triangles formed by using the "lengths of the ladder" as a hypotenuse and the "height above ground" as the altitudes. [These are (3,4,5) and (6,8,10) right triangles], 2) The student recognizes that the triangle formed by the 16 foot high pole, the ground, and the entire length of the ladder is similar to the 2 triangles in step # 1, and 3) By setting up the proportion: 4 feet (height) is to 5 feet (hypotenuse) as 16 feet (height) is to "L" feet (hypotenuse),  $4/5 = 16/L$ ,  $L = 20$  feet, the length of the ladder.

#### **Score - 1 Partial solution - (Slightly)**

**1) The student appears to have a plan and utilizes at least one of the givens or other knowns in the problem, but he or she has not completed enough of the problem to**

**determine if their direction taken would end in a correct solution.**

1) The student recognizes that there are 2 right triangles formed by using the "lengths of the ladder" as a hypotenuse and the "height above ground" as the altitudes. [These are (3,4,5) and (6,8,10) right triangles]

**Score - 0      Invalid response - (Definitely Not)**

**The student has used markings, notations terminology theorems and definitions incorrectly or inappropriately throughout the solution, and the correct objective has not been recognized.**

**APPENDIX F**

**Table of Specifications on the Correlation between  
Concepts on the POW's and the PST**

Table of Specifications on the Correlation between Concepts in the POW's and the PST

**Concepts Needed for Solution of Problem-Solving Test Questions**

<b>POW</b>	1 A	1 B	1 C	1 D	2 A	2 B	2 C	3 A	3 B	3 C	3 D	4 A	4 B	5 A	5 B	5 C
1														X	X	X
2	X	X	X	X				X	X							
3												X	X			
4						X	X									
5												X	X			
6			X				X									
7					X											
8	X			X			X	X	X							
9														X	X	X
10		X	X		X	X										

Concepts Needed for Solution of Problem-Solving Test Questions:

**PST Problem 1**

- (A) Base Angles of an Isosceles Triangle are Congruent
- (B) Definition of Supplementary Angles
- (C) Solve an Algebraic Equation with One Unknown
- (D) Sum of Measures of Interior Angles of a Triangle

**PST Problem 2**

- (A) Coplanar lines perpendicular to the same line are parallel
- (B) Coplanar Parallel Lines cut off Proportional Sections on Multiple Transversals
- (C) Solution of Ratio and Proportion Problem

## PST Problem 3

- (A) Base Angles of an Isosceles Triangle are Congruent
- (B) Sum of the Measures of the Interior Angles of a Triangle
- (C) Location of the Longest Side of a Triangle based on the Measure of the Interior Angles
- (D) How to Logically determine the largest side if more than one triangle is involved

## PST Problem 4

- (A) Formulas for the areas of a circle and square
- (B) Concept of Conservation of Space

## PST Problem 5

- (A) Could be solved by Hero's Formula
- (B) Definition of Area of a Triangle
- (C) Recognition of Right Triangle by Pythagorean Triple

**APPENDIX G**

**McBride Problem Solving Test with Scoring Rubric**

## NOTE TO USERS

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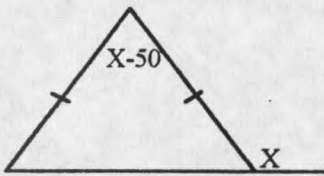
Appendix G  
134-135

UMI

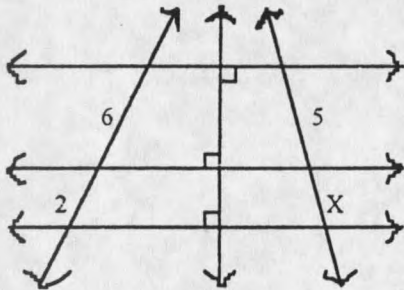
Problem-Solving Test

**General instructions:** Show all work. If you use a calculator, show how you set up the problem.

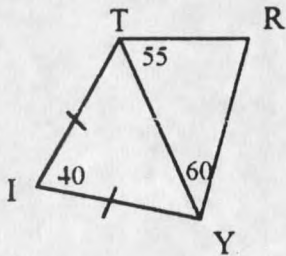
1. Solve for X.



2. Solve for X



3. Name the **smallest** segment (side) in the diagram.  
Explain your choice.



The diagram above may be drawn inaccurately.

4. Find the area of the shaded region. The diameter of the circle is 10.



5. Triangle ABC has sides 3, 4, and 5. Triangle XYZ has sides 3, 4, and 6. Which triangle, ABC or XYZ, has the larger area? Explain your answer.

Extra: If you were stumped by a problem, explain what you believe you needed to know in order to reach a solution.

Permission to reprint the McBride Problem Solving Test was received from Bethe McBride, author of the test.

**PROBLEM SOLVING SCORE SHEET**

- (Code 0) Only negative indicators (Contra indicated)      (Code 3) Mostly positive indicators (Mostly)  
 (Code 1) No indications or indeterminant (Can't tell)      (Code 4) Indicators are all positive (All)  
 (Code 2) Only a few positive indicators (Slightly)

SUBJECT # \_\_\_\_\_ SCORER \_\_\_\_\_

**Standard I**

- 1) **The student appears to understand the terms, notation, and diagram markings of the problem.**  
 Apply the above codes to: Specify

Item 3—Positive Indicators present (code)	T	N	M	Other	Net
Item 4—Positive Indicators present (code)	T	N	M	Other	Net
Item 5—Positive Indicators present (code)	T	N	M	Other	Net

**Standard II**

- 2) **The student has determined the known information and the objective of the problem.**  
 Apply this above codes to: Specify

Item 3—Positive Indicators present (code)	S	V	O	Other	Net
Item 4—Positive Indicators present (code)	S	V	O	Other	Net
Item 5—Positive Indicators present (code)	S	V	O	Other	Net

**Standard III**

- 3) **The student exhibits knowledge of pertinent definitions, postulates, theorems, etc., and key visual formations of the problem.** Apply the above code to: Specify

Item 1—Positive Indicators present (code)	D	T	V	Other	Net
Item 2—Positive Indicators present (code)	D	T	V	Other	Net
Item 4—Positive Indicators present (code)	D	T	V	Other	Net

**Standard IV**

- 4) **The student has a strategy or plan to accomplish what he or she intends and knows when and how to breakup the problem.** Apply the above code to: Specify

Item 1—Positive Indicators present (code)	P	B	Other	Net
Item 2—Positive Indicators present (code)	P	B	Other	Net
Item 3—Positive Indicators present (code)	P	B	Other	Net

**Standard V**

- 5) **The student can make deductions and present an effective proof. [The student can effectively explain her answer or carry out the calculations and can present a correct solution.]**

Apply the above code to: Specify

Item 1—Positive Indicators present (code)	D	C	FD	R	Other	Net
Item 2—Positive Indicators present (code)	D	C	FD	R	Other	Net
Item 5—Positive Indicators present (code)	D	C	FD	R	Other	Net

**APPENDIX H**

**Student/Parent Research Participation Permission Form**

## APPENDIX H

## Student/Parent Research Participation Permission Form

## PARENTAL PERMISSION FORM FOR STUDENT RESEARCH PARTICIPATION

Dear Parent or Guardian,

Your son or daughter's class is participating in research related to geometry. I am trying to statistically determine some of the factors that contribute to success in geometry. These factors could range from student attitudes towards mathematics to basic geometric facts and geometric problem solving ability. To determine some of the factors that may be affecting your child's performance in Geometry, it is necessary to administer a series of tests. The first two will be administered the week of January 5-9, 1998.

Naturally, I want you to be informed about this research. The tests are either multiple-choice, problem solving, or Measure of Agreement (Strongly Agree to Strongly Disagree). There are no personal or private questions, and the test scores will be kept strictly confidential. The object is to find group patterns and not to study individuals. If you are interested in the content of the tests, copies are available through your child's Geometry teacher.

Lastly, while these tests are being administered to your son or daughter's Geometry class, if for some reason you do not want your child to participate in the study, you have the right to refuse to allow his or her test scores to be put in the data pool. The form below is to be detached and returned to your child's Geometry teacher.

**PARENT or GUARDIAN:** Please write your **child's name** in **(ONE)** of the two blanks below, either selecting that you **DO** give permission, or **DO NOT** give permission for test data inclusion and then **sign the form at the bottom** designated Parent or Guardian. Then, **have your child return this entire form to his or her Geometry teacher.**

---

I **DO** give permission for \_\_\_\_\_ test scores to be included in the research data pool. (Printed Student's Name)

I **DO NOT** give permission for \_\_\_\_\_ test scores to be included in the research data pool. (Printed Student's Name)

Signed (Parent or Guardian) \_\_\_\_\_

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