1992

An Investigation of the Relationship between Participation in the Odyssey of the Mind Program and Mathematical Problem Solving Achievement

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AN INVESTIGATION OF THE RELATIONSHIP BETWEEN PARTICIPATION IN THE ODYSSEY OF THE MIND PROGRAM AND MATHEMATICAL PROBLEM SOLVING ACHIEVEMENT

by

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A Dissertation Submitted to the Faculty of the Graduate School of Loyola University of Chicago in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy
January
1992

Dedicated to my parents
whose pride and encouragement
motivated me to continue my education
and to baby Ashley
who was born in the
middle of this whole thing

ACKNOWLEDGEMENTS

The help and assistance given to me by many people during this project is gratefully acknowledged. Of particular note, are the contributions of my committee members. Dr. Diane Schiller, Chairperson of the committee, who suggested the topic for this dissertation and whose scholarly advise, expertise, and support guided me through to completion of this project. Dr. Jack Kavanagh who gave me extensive help with all of the statistical aspects of this dissertation. Dr. Ron Morgan whose red editing pen helped me to express the text in a more effective way and Dr. Todd Hoover whose knowledge of SPSSX cleared up an error message and allowed the statistical tests to run.

The help and understanding of family and friends is also greatly appreciated. In particular, I am forever grateful for the continued support, love, and encouragement of my husband Richard throughout this project and other endeavors during the time in which we have known one another.

VITA

The author, Terri Spreckman Carman, was born November 29, 1957 in Chicago, Illinois.

In December 1978, she received the degree of Bachelor of Science in education from the University of Illinois in Champaign. In May of 1983, she earned the Master of Education degree from National College of Education in Evanston, Illinois. She received a Master of Arts degree and a Type 75 Administrative Certificate from Northeastern Illinois University in May of 1986.

In 1979, she began teaching 5th grade in Bensenville, Illinois. During the summer of 1979, she started teaching children of migrant workers in a yearly summer school program in Palatine, Illinois. In 1981, she developed and taught in a program for gifted students in the fourth to sixth grades in Bensenville, Illinois. In 1990, she worked as an assistant principal at Blackhawk Junior High School in Bensenville. In 1991, she became the principal of Chippewa School in Bensenville and is currently in that position.

In addition to her work in Bensenville, she also serves as the Odyssey of the Mind regional and tournament director for the state of Illinois. Her Odyssey of the Mind teams have been featured several times in the Chicago Tribune.

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CHAPTER I

INTRODUCTION

"The past lies upon the present like a giant's dead body." In many respects, this quote taken from Hawthorne's House of Seven Gables (in Powell, 1985 p. 448) serves as a useful descriptor related to the lack of change made in education throughout history. The study to be described below takes place at a time when the education system is reported to be failing a large number of students and teachers because it is organized to meet the challenges of the 19th, not the 21st century. David Kearns and Dennis Doyle (1988) make the case in their book, Winning the Brain Race, that the contemporary school is an outgrowth of the scientific management movement of the early 20th century. According to them, the most important part of that movement was the belief that regimentation fostered efficient productivity. The teacher was to be the worker who manned the production line and the student was considered to be the product. That is to say that the educational system was designed to respond to the masses, pour knowledge into students and get the teachers to work at their maximum capacity, while running few, if any, risks. Kearns and Doyle claim that it was anti-intellectual and hostile to creativity, innovation and entrepreneurship. It was an educational bureaucracy, the purpose of which was to suspend the exercise of judgement. It was an educational assembly line, designed to produce a perfectly uniform product by using production processes that employed the labor of people smart enough to follow the Teacher's guide. To be fair, it did fit the society of the time. In a matter of decades, the United States went from an agrarian to an industrial economy and is now rapidly moving through the post industrial era where the majority of the educated workforce operates not with their hands but with their minds. The 1950's and 60's saw one of the largest and most sustained educational reform movements in American history. However, when Goodlad (1983) visited classrooms in the 1980's, he found things were much the same as they had been twenty years ago. The primary emphasis was still on the teacher providing basic information to passive learners.

More and more of our nation's business people, organizational leaders, and society in general are becoming increasingly concerned with the quality and relevance of educational outcomes. Educators should ask more of students than that they be walking memory banks or sponges quickly absorbing information. It is not sufficient to only teach content. Machines can store information more accurately and retrieve it faster than humans can. The modern employee must be more highly educated, better informed, more flexible than ever before, able to think, solve problems, make informed judgements, distinguish between right and wrong, and discern the proper course of action in situations and circumstances that are necessarily ambiguous.

In tomorrow's work force, there will have to be decision making all along the line, not merely at the top. To learn to take responsibility for making decisions, children need to acquire critical thinking skills that will enable them to analyze, synthesize and solve problems. Kearns and Doyle (1988) found that employees in high-tech companies are encouraged to experiment "above the waterline". The employees are asked to be innovative, experimental, and entrepreneurial in ways that will not "sink" the company if they go wrong. Stephanie Schoumacher and Vivian Cadden (1989) believe that if the United States is to compete internationally and maintain an expanding economy and a high standard of living, its children will have to possess a higher order of thinking skills and be able to work cooperatively. Schoumacher and Cadden (1989) suggest that if we are to compete successfully in a global economy, we must learn how to be noncompetitive with one another. They say collaboration, cooperation and teamwork, rather than individual achievement will be the mark of an advancing society.

In its Curriculum and Evaluation Standards for School Mathematics, (Standards) (1989), the National Council of Teachers of Mathematics (NCTM) also reported the changes our country (as well as all industrialized countries) has gone through in changing from an industrial to an information society. The NCTM says this social and economic shift can be attributed, in part, to the availability of low-cost calculators, computers, and other technology. The use of this technology has dramatically changed the nature of the sciences and business. The NCTM says this shift has transformed both the aspects of mathematics that need to be transmitted to students and the concepts and procedures they must master if they are to be self-fulfilled, productive citizens in the next society.

In the NCTM's Standards, Henry Pallak, an industrial mathematician, listed the following among the mathematical expectations for new employees in industry:

- The ability to work with others on problems
- The ability to see the applicability of mathematical ideas to common and complex problems
- Preparation for open problem situations since most real problems are not well formulated

Isaksen and Parnes (1985) stress the importance of creative planning and problem solving in curriculum planning. They say:

> learning which promotes the development of creative thinking and problem-solving skills is important for a society with an emphasis on democracy and innovation. People capable of making effective decisions are essential for the functioning of a democratic society. Society also needs to bring its most creative thinkers to bear on some of its basic problems.

Purpose of the Study

If the goal of the educational system in this country is to prepare its youngsters for tomorrow's work force, and if tomorrow's jobs require creative thinking, problem-solving abilities, teamwork and cooperation, then one must discover ways and means to improve the educational enterprise so that the nation's companies can remain competitive and strong. What are some ways and means to improve the school's ability to teach creative thinking, problem-solving, teamwork and cooperation? Certainly ways and means which have demonstrated their ability to improve the educational system are very useful and are indeed needed.

The area of mathematics has always been one in which students were required to solve problems. In recent years, there has been a strong reform movement to improve the way in which mathematics is taught and to update the mathematics curriculum so that it includes the advances in technology. According to Standards, problem solving should be the central focus of the mathematics curriculum; viewed as a concept that can be integrated into every part of the school mathematics program and provide the foundation for learning all concepts and skills. Outside of the mathematics classroom, problem solving experiences have been scarce. However, in recent years, reform has been called for to make the teaching of thinking a central part of the curriculum.

The force behind this reform comes mainly from two bodies of research. The first source is from research that has revealed and analyzed poor performance by students on complex tasks. The second source is from research that has documented children's capabilities for complex thinking and reasoning on which current curricula are not building.

In 1964, the International Association for the Evaluation of Educational Achievement conducted its first cross-national study in six subject areas including mathematics. The math study involved 21 countries and was targeted at students in grades 8 and 12. The results of the 1981 assessment showed that the best United States students could do as well as students in other countries but as a group their performance was below that of their counterparts in other countries (Brodinski, 1985).

One of the most well-known bodies of research is actually a set of recommendations that the NCTM published in 1980 called An Agenda For Action. The Agenda for Action's intent was to effect positive change during the decade. It was an agenda that set out the areas on which focus was needed (Hill in NCTM, 1981).

Several reports emerged prior to the preparation of the Agenda for Action. The newly emerged data base helped to provide background information so that a realistic agenda could be created. The first study was completed in 1975 by the National Advisory Committee on Mathematical Education. It analyzed data about mathematics programs, K-12. Following this report, the National Science Foundation conducted several studies on classroom practice. At about the same time, the National Assessment of Educational Progress conducted its second round of mathematics assessment. The information gathered from each of these studies gave the National Council of Teachers of Mathematics a data base from which to create the agenda (Hill in NCTM 1981).

The National Assessment of Educational Progress (NAEP) conducted math assessments in 1973, 1978 and 1982 and 1986 of 9-,13-, and 17-year old students. Each of these assessments involved nationally representative samples of each of the age groups. The assessments included both open-ended and multiple-choice questions covering a wide range of content and process areas. One of the content areas on the tests was that of higher-level applications in numbers and operations. This area measured a deeper understanding of the concepts and relationships between numbers. Students had to use problem solving processes in addition to their knowledge and under-standing skills. They had to identify and implement an appro-priate strategy, screen relevant from irrelevant information, recognize patterns and describe or symbolize the relationships (Dossey, Mullis, Lindquist & Chambers, 1988). In 1985, Brodinski reported that of the three age groups, only the 13-year olds improved significantly in overall math performance between 1978 and 1982. However, in 1988, the Educational Testing Service published results from the 1986 NAEP assessment which showed recent improvements for all three age groups (Dossey et al., 1988).

Statement of the Problem

Due in part to the reform movement, many instructional materials and programs for teaching problem solving or thinking skills have begun to appear in the schools. Is it possible that participation in these thinking programs can help students do better in school or in particular, the area of mathematical problem solving? The overall purpose of the study to be described here is to carefully examine a creative problem solving program, called "Odyssey of the Mind" (OM), and investigate if there is a positive transfer of learning from students who have participated in this program to the area of general mathematical problem solving.

Research Questions:

The study was designed to address the following seven research questions.

1. Are there significant differences in mathematics problem solving achievement between seventh grade gifted math students who have participated in the Odyssey of the Mind Program and those who have not participated in the program?

2. Are there significant differences in mathematics problem solving achievement between seventh grade regular math students who have participated in the OM Program and those who have not participated in it?

3. Do significant relationships exist between OM participants' mathematics problem solving achievement and the amount of time spent in the OM program?

4. Do significant relationships exist between OM participants' mathematics problem solving achievement and the level of competitive success attained in the OM program?

5. Are there significant differences in creative problem solving achievement between seventh grade students who have participated in the OM Program and those who have never been involved in it?

6. Are there significant differences in teacher ratings of student problem solving ability between students who have participated in the OM program and those who have not participated in it?

7. Are there significant differences in student confidence as related to problem solving ability between students who have participated in the OM program and those who have not participated in it?

Significance of the Study

By empirically documenting that positive transfer of learning can take place between a general creative problem solving program and mathematics, educators will see that there are more creative, interesting, and interdisciplinary approaches which can result in higher levels of student achievement. It will also show that the effects of learning can go beyond the goals of a specific program.

The possible theoretical implications of this study rest on its potential to establish an empirically derived research base concerning OM and transfer of learning to other subjects. Previous to initiating this study, there has been only one research study reported in the literature which directly involved Odyssey of the Mind. This study was conducted by Gloria Fleischer Cohen in 1986 at Columbia College. Cohen wrote a descriptive case study documenting the characteristics and experiences of selected students who participated in OM.

The results of the study described here could lead to an increased awareness of the importance of having students become active problem solvers and creative thinkers. The increased awareness could influence the type of curriculum content required in schools at all levels and eventually improve the thinking capabilities of employees in the work force.

Odyssey of the Mind

In response to the fairly recent demand for the curriculum and schools to begin teaching students how to think, many publishers have created a wide range of thinking skills curriculum materials. There has also been a growing number of academic bowls and problem solving contests being offered for academically talented and/or creative students.

A number of these programs appear to be based on rote memorization and recall of facts. It is questionable whether these types of programs offer any long lasting effects on student achievement. However, another type of program is concerned with the creation of solutions to problems which have not yet been solved. These programs involve the use of divergent thinking. Divergent problems are "open ended", that is, they have numerous acceptable solutions. Students have greater opportunity to think critically, analyze a problem, formulate alternatives to it, then synthesize a solution that they feel is the best approach to solve the problem. Decision making becomes a continuous process.

The Odyssey of the Mind Program (OM) would be included in this "open ended" group. OM is considered by its founder, Sam Micklus, to be a creative approach to education. Micklus is a professor of technology at Glassboro (New Jersey) State College, who started the competition in 1978 with 28 schools in New Jersey. Since then, it has grown into an annual event involving nearly 8,000 schools and organizations in the United States, Canada, China, Japan, Mexico, Poland and the Soviet Union.

OM is a program for creatively gifted students who are capable of developing unusual ideas and insights. It was intended to provide nonathletically gifted students with a highly visible, enthusiastically-supported education based on a varsity sports model (Gourley, 1981). The OM Association credits much of the success of its program to its unique approach that involves students' imaginations in solving "hands-on", or activity oriented, fun-filled problems as creatively as possible (1989b). Micklus believes the aim of the program is to help people consider possibilities rather than limitations, a goal he believes conventional education largely ignores (1989b).

Each year, OM offers teams of students five problems from which to choose. Three of the problems are related to science and technology and the remaining two involve the language or performance arts. Micklus says different kids have different kinds of talents. The idea is to have a set of problems that interest and challenge all of them in one way or another (Bakke, 1987).

Teams are scored on the effectiveness with which they solve the problems. In addition to the long-term challenge it selects, each team must also compete in two other areas; spontaneous problem solving and style. Gourley (1981) reported a concern of Sam Micklus was that the solution was the work of the students and not the adults. To allay this fear, spontaneous problems were created. At the competition, each team is scheduled into a room and is asked to solve a spontaneous problem which they have never seen before. No coaches or spectators are allowed to be present during this activity.

The final area in which teams are judged is in style. Gourley (1981) reported that this is what Torrance calls elaboration and what General Motors calls "extras". In

Odyssey of the Mind, style includes costumes, dramatics, music and decoration. It is anything that is added to the solution which is related to the problem, but not required as part of the solution. A team's total score is a combination of long-term, spontaneous, and style points.

Team members and coaches are often selected from volunteers based on their skills, similar to the way students try out for teams in varsity sports. Gourley (1981) states that high academic achievement and exceptionally high IQ scores are not essential characteristics of team members. A high degree of imagination was seen as the predominant characteristic. Students' self-nomination and teacher-nomination are used in the identification of team members. Just as in sports, the success of the teams appears to stem from their skill, time on task, and from parent support. Overall, the reported success of the OM program has demonstrated that the athletic competition model can be used in a program designed for creatively gifted students.

Micklus reported that many educators mistakenly believe that in order to be creative one must have artistic ability or a high IQ. In fact, however, an individual may be creatively gifted and yet score lower than average on standardized tests (OM Association, 1990). Most creative individuals tend to be divergent rather than convergent thinkers. And since IQ tests measure convergent thinking, many creative students do not distinguish themselves when tested this way. Micklus says the tragedy is that many schools rely upon IQ information to discover creative potential and thus miss identifying the creative person (OM Association, 1990).

The Odyssey of the Mind Program attempts to inject humor into problem solving whenever possible because it is believed that humor is generally very important to creative people. The OM Association believes that being curious and having fun is natural for young people. If curiosity and fun are combined in an instructional program, it may prove to be the best way to motivate children (OM Association, 1989b).

Coaches are offered a coach's training session by the OM state association. The workshop consists of a history and overview of Odyssey of the Mind, selection and training of students, rules for competition, and the statewide program organization. In addition to this, the OM Association sends a program handbook to each of its members. The booklet contains all of the rules, tournament procedures and helpful suggestions for the coach.

While there is no substantial evidence that creativity training actually generalizes beyond the classroom door to everyday behavior; contests and competitions have been shown to be useful as focused goals and as an objective means of testing one's mettle in real life situations (Castiglione, 1986). The focus on realistic problems is one of the five following similarities seen between the Odyssey of the Mind Program and the new problem solving direction for mathematics instruction.

Similarities Between New Math Goals and OM

1. Real-life experiences:

A new emphasis on application in the real world is among the changes taking place in the math curriculum. Math teachers are being encouraged to teach topics that are relevant to the students' day-to-day lives.

In Making the Case for Math, A Special Report for Elementary Mathematics in the 1990's , Landsmann and Harbaugh (1989) state that an understanding of math can help children interpret the world and solve problems that occur in it. Students need to know that the problems people solve in real life everyday are not easily solved. A person doesn't just take all the numbers involved in a problem and apply a formula to them like students do so often with traditional textbook problems.

Edward Manfreis, (in Landsmann & Harbaugh, 1989) says that students need to be given problems that take time to solve and the time to solve them. The long-term problems on which students work in Odyssey of the Mind are complex problems like the ones described for the new direction of math in the 1990's and take a long time to solve like real-life experiences.

Many of the OM problems are related to current problems in society. For example, one of the problems in 1989 was called "Recycle". The problem made students aware of the growing trash crisis and the importance of recycling. As part of their solution, blindfolded team members had to pick up 35 pieces of trash and sort them into three different bins in a recycling center.

2. Across discipline areas:

The NCTM (1989) says that math learning activities should incorporate topics and ideas across mathematics areas. For example, an instructional activity might involve problem solving and use geometry, measurement and computation. All mathematics should be studied in contexts that give the ideas and concepts meaning.

The NCTM (1989) stresses that students should have many opportunities to observe the interaction of mathematics with other school subjects and with everyday society. They say that many opportunities to show the connections between mathematics and other disciplines are missed in school. Mathematics (especially measurement) arises in science, social studies, home economics, industrial technology, and physical education and is increasingly important to teachers of these subjects.

Students must use knowledge and skills from many different discipline areas in order to solve problems in Odyssey of the Mind. For instance, a long-term problem in 1989 was entitled "Geographic Odyssey". Students had to create a vehicle which could travel around the world (in actuality, a gymnasium) and stop at various countries which they had to accurately portray. In order to solve the problem, student team members had to use industrial technology skills, math calculations and measurements, social studies knowledge, art skills and conduct library research.

3. Active student involvement:

The NCTM (1989) emphasizes that mathematics learning should engage students both intellectually and physically. Students must become active learners, challenged to apply their prior knowledge and experience in new and increasingly more difficult situations. They say that instructional approaches should engage students in the process of learning rather than transmit information for them to receive.

The Odyssey of the Mind program is set up so that students have constant "hands-on" active involvement in their learning. The student team members must do all the work. Adult coaches are present to serve as facilitators. The OM coach's training handbook (1989) states that a coach's help should be Socratic in nature. Appropriate questioning techniques, discovery through trial and error, research and knowledge gained through the use of mentors should be used by a coach in the process of team guidance. Adult assistance is so strongly discouraged that all team members and coaches must sign an outside assistance form stating that the students designed all problem solutions, props, and costumes themselves. If a team designs a solution that it cannot produce, then it must redesign the solution or parts of it so that they can produce it without help.

4. Estimation and multiple solutions:

One of the new areas of emphasis in math for the 1990's is estimation. Students are being taught that in many situations it is not necessary for a person to know the exact answer to a problem, but that an approximate one will do just fine. For example, if a student is in a grocery store and has $20.00 in his pocket, he should have strong enough math skills and practice in using estimation to know if he will have the money he needs to make his purchases. With estimation, students can learn that there can be several different solutions or more than one way to find an answer to a problem.

Teachers are being encouraged to look at how their students solve problems and arrive at their answers. That is to say that the processes children use in working problems is as important as the solution. Since problem solving has two aspects; a thinking process and a final product, it is not sufficient to evaluate just the thinking process or just the final product. Consideration of both aspects of the problem is required. This is very different from the math of yesteryear when the teacher only cared about the answer.

Many suggestions have appeared recently in mathematics books and journals for teachers to use in evaluating students' problem solving process. One suggested method is focused holistic scoring. It focuses on the total solution, not just on the answer. It is considered focused because one number is assigned according to specific criteria related to the thinking processes involved in solving problems.

For example, zero points would be given if an answer was incorrect and no work was shown. One point would be awarded if an inappropriate strategy was started but not carried out. Two points would be given if the student used an inappropriate strategy and got an incorrect answer, but the work showed some understanding of the problem. Three points would be awarded if the student implemented a solution strategy that could have led to the correct solution, but he or she misunderstood part of the problem or ignored a condition in the problem. Four points would be given if the student made a computational or copying error in carrying out an appropriate solution strategy. Five points would be awarded for a correct answer and appropriate strategy (Charles, Lester,O'Daffer, 1987).

In Odyssey of the Mind, final scores of the long-term problems are based on the successfulness of the solution on the day of the competition as well as the artistic or creative components of the solution which were prepared in advance. Even if the teams' solution is a complete failure on the day of the competition, they have a chance of winning a special creativity award. The creativity award is presented to teams or individuals who exhibit exceptional creativity. Success is not a criterion for winning the award. Sam Micklus designed this to encourage risk taking when solving problems. Micklus believes that this award is the essence of the Odyssey of the

Mind Program (Micklus and Micklus, 1989).

Divergent thinking or multiple solutions is never more apparent than it is at an Odyssey of the Mind competition. If thirty teams compete on a problem, there are usually thirty different solutions presented for it. The different solutions are not considered right or wrong, but some demonstrate better or more efficient ways of solving the problem than others do. The fascinating part for the spectators is seeing the different processes each team used to get to their solution.

5. Group versus individual work:

In Standards (1989), it is stated that classroom mathematics activities should provide students the opportunity to work both individually and in small and large group arrangements. Individual work can help students develop confidence in their own ability to solve problems but should constitute only a portion of the middle school experience. Working in small groups provides students with opportunities to talk about ideas and listen to their peers, enables teachers to interact more closely with students, takes positive advantage of the social characteristics of the students (especially at the middle school level) and provides opportunities for students to exchange ideas.

Odyssey of the Mind stresses teamwork. Students work on teams of five to seven members. Micklus (1989) says the teamwork, cooperation and communications that are required of the individuals who serve on an OM team are invaluable training for performing with a project team in a corporation. He says many companies are just now learning the value of this size group and the dynamics that can occur. During the spontaneous problem solving portion of the OM program, if a member of the team gets stuck or can't think of a solution to the problem, the whole team is stuck until an answer is given by the asked upon student. Students learn how a group approach can best be used when faced with a problem.

CHAPTER II

REVIEW OF LITERATURE

The major focus of this study was to investigate transfer of learning in the area of problem solving. With that purpose in mind, the selective review of the literature is cast within a problem solving and transfer of learning theoretical framework. In this chapter a review of studies related to the definition and process of problem solving and changes in mathematics instruction is presented. Following this, studies which involve types of learning, teaching for transfer, and factors which affect transfer of learning are reviewed.

Views and Definitions of Problem Solving

The three most common interpretations of problem solving are as a goal, a process, and a basic skill (Branca in Krulik and Reys, 1980).

Problem solving as a goal:

"The real justification for teaching mathematics is that it is a useful subject, and, in particular, that it helps in solving many kinds of problems" (Begle in Krulik and Reys, 1980 p. 3).

Problem solving as a process:

The National Council of Supervisors of Mathematics defined problem solving as the "process of applying previously acquired knowledge to new and unfamiliar situations" (National Council of Supervisors of Mathematics in NCTM Krulik and Reys, 1980 p. 3). The emphasis in this view of problem solving is placed on the methods, procedures, and strategies that students use in solving problems.

Problem solving as a basic skill:

Problem solving has been frequently mentioned in reports concerned with identifying the basic skills that individuals need to function in society. In this interpretation of problem solving, the emphasis is placed on the specifics of problem content, problem type and solution methods.

A common belief in recent years is that solving problems is the essence of mathematical learning and that the body of mathematical knowledge is merely the set of tools available for the active process of problem solving.

Rowe (1985) and Gagne (1988) confirmed the importance of problem solving when they made the following statements. Rowe said the ability to solve problems was a prerequisite for human survival (in ASCD, 1988). Gagne commented that problem solving was the highest form of learning (in Orton, 1987).

The meaning of problem solving has changed. During the early 1970's, problem solving meant the solving of verbal or word problems. While verbal problems are still used, the term problem solving now includes nonroutine mathematics problems and real (application) problems (Kantowski in Fennema, 1981).

A problem is commonly thought of as nonroutine if the person attempting the problem knows no clear path to the solution and has no algorithm at hand that will guarantee a solution. In order to solve the problem, the person must put together the available knowledge in a new way. Orton (1987) supported this definition of nonroutine problem solving and stated that problem solving is "now normally intended to imply a process by which the learner combines previously learned elements of knowledge, rules, techniques, skills and concepts to provide a solution to a novel situation" (p.35). It is not the set of routine exercises found at the end of a chapter in a mathematics textbook.

Krulik and Rudnick (1984) believe a problem requires thought and synthesis of knowledge. They said this is different than a question that could be answered through immediate recall or memory. It is also different from an exercise that gives a student drill and practice. Krulik and Rudnick defined a problem as "a situation that confronts an individual, that requires resolution, and for which the individual sees no apparent or obvious means or path to obtaining a solution" (p. 4). Marshall's (in Silver, 1988) definition of problem solving matched the others when she said it was an individual's proficiency in organizing the knowledge and coordinating it within a new, unfamiliar situation.

Marshall said "a distinction was usually made between situations in which an individual does not know what to do and those that are merely repetitions of previous experiences" (in Silver, 1988 p. 160).

According to Gestalt psychologists, problem solving is a search to relate one aspect of a problem situation to another. This process results in structural understanding—the ability to comprehend how all the parts of the problem fit together to satisfy the requirement of the goal. This involves reorganizing the elements of the problem situation in a new way so that the problem can be solved (Mayer, 1977).

In contrast, the Associationists view problem solving as the trial and error application of preexisting response tendencies (habits). They label the problem the stimulus; the problem solving behavior the responses; and the links between a particular stimulus and a particular response the associations (Mayer, 1977). The Associationists assumed links are in the problem solver's mind where they formed a family of possible responses related to given problem situations (Mayer, 1977).

Changes in Mathematics Instruction

Since the time of Plato, support has been given to the idea that studying mathematics could improve a person's ability to think, to reason, and to solve problems they would confront in the real world (Stanic and Kilpatrick in Charles & Silver, 1988). The teaching of mathematics in American elementary schools has passed through three major phases during the past century. These phases consist of the <u>drill and practice phase,</u> the <u>meaningful arithmetic phase,</u> and the <u>new math phase.</u> (Kroll in Trafton & Shulte, 1989).

From approximately 1920 to 1930, drill and practice was the main focus in mathematics instruction. Edward Thorndike was a leading theorist with his associationist theory. Kroll (1989) said a major effect of Thorndike's theories was the regimentation of the mathematics curriculum into many disjoint bits (in Trafton & Shulte, 1989).

From approximately 1930 to 1950, the progressive education movement was prominent in the United States and there was a new emphasis on "learning for living". Mathematics instruction changed from drill for drill's sake to attempts to develop arithmetic concepts in a meaningful way. Mathematics was learned in order to acquire the tools for dealing with problems encountered in later life.

Students during this time were not taught by systematic teaching but rather through an activity-oriented approach or incidental experience. The mathematical experiences were often very diverse and unstructured so that children were unable to interrelate the different bits and pieces.

Meaningful arithmetic developed into the meaning theory of arithmetic. This new theory emphasized understanding mathematical relationships. It attempted to combine the progressive idea of activity learning with the ideas of

Gestalt psychologists. "Rote memorization was deemphasized and activity-based discovery was used to help children see connections among the many discrete skills and concepts they were learning" (Kroll in Trafton & Shulte, 1989 p. 205).

During the 1960's, the new math curriculum became prominent. A major change was its attempt to introduce abstract but fundamental ideas early in the curriculum. Lessons were included on new topics such as sets, numeration systems, intuitive geometry and number theory (Kroll in Trafton & Shulte, 1989).

Kroll (1989) suggests that mathematics instruction today reflects parts of all of the past phases. She also believes that we might be entering a fourth major phase in mathematics education. This new phase appears to reflect the influences of a recent psychological theory called 'constructionism'. The constructionist theory emphasizes that individuals approach new tasks with prior knowledge, they assimilate new information, and they construct their own meanings. Students are no longer thought of as passive absorbers of information (in Trafton & Shulte, 1989).

<u>Problem Solving Instruction</u>

Problem solving instruction has a long history in the math curriculum. However, teaching strategies have changed from simply presenting students with problems to developing more general approaches to problem solving.

In 1978, Hatfield (in Trafton & Shulte, 1989) studied rationales for problem solving instruction. He distinguished between three different types of teaching.

1. Teaching <u>about</u> problem solving. This refers to instruction that focuses on strategies for solving problems.

2. Teaching <u>for</u> problem solving. This instruction focuses on application. It uses real life problems as a setting in which students can apply and practice recently taught concepts and skills. It delays problem solving until after the introduction of a topic or computational skill and then presents a sample problem to illustrate the taught method.

3. Teaching <u>via</u> problem solving. This instructional model uses a problem as a means of learning new mathematical ideas and for connecting new and already constructed mathematical notions. Students learn concepts and develop skills as they solve problems that incorporate important elements of the mathematical content being studied.

Charles, Lester, and O'Daffer (1987) identified the following seven goals for teaching problem solving:

1. To develop students' thinking skills.
2. To develop student's abilities to select and use problem solving strategies.
3. To develop helpful attitudes and beliefs about problem solving.
4. To develop students' abilities to use related knowledge.

5. To develop students' abilities to monitor and evaluate their thinking and progress while solving problems.

6. To develop students' abilities to solve problems in cooperative learning situations.

7. To develop students' abilities to find correct answers to a variety of types of problems.

A continuing controversy in the problem solving literature concerns whether students should be taught specific strategies for solving various types of problems or whether they should be taught one or more general strategies that would apply to many problem types.

Researchers have used two different methods for identifying effective problem solving strategies that work. One method involved studying the performance of experts; the other involved attempts to give problem solving abilities to computers.

Wallas (1926) broke the process of problem solving into four smaller stages. They consisted of the following (in Mayer, 1977):

1. Preparation - the gathering of information and preliminary attempts at a solution.

2. Incubation - putting the problem aside to work on other activities.

3. Illumination - the appearing of the key to the solution (also known as the 'flash of insight' or the 'aha' stage).

4. Verification - checking the solution to make sure it works.

In 1945, George Polya, an eminent mathematician led the way in establishing a routine for mathematical problem solving and in developing training procedures to help people to become better problem solvers. Polya identified mental operations or strategies which he called heuristics that were typically useful for the solution of problems. He then provided direct instruction in these strategies.

Polya (1945) believed a method was a device which one used twice. If that method succeeded twice, the individual might use it when faced with another similar problem. In that way, a method became a strategy.

In his text, How to Solve It, Polya outlined a four-step method for problem solving.

1. Understand the problem
2. Develop a plan
3. Carry out the plan
4. Reflect on one's work

Polya suggested several methods for use in developing a plan such as drawing a picture, guess and checking, and using simpler numbers. Polya believed it was important to make sure the unknown, the data and the conditions of a problem were understood (in Nickerson, 1985). These strategies are still widely used in textbooks today.

Mayer (1977) believed Polya's steps were similar to Wallas' stages. Polya's understanding step was similar to Wallas' preparation phase; his developing a plan included part of Wallas' preparation phase and both the incubation and illumination phases; and the carrying out the plan and looking back steps related to Wallas' verification stage.

Schoenfeld (1985) concluded that while the literature of mathematics education is full of heuristic studies, few provided concrete evidence that heuristics made a difference.

Schoenfeld (1985) pointed to the studies of Wilson (1967) and Smith (1973) as examples of his point. These studies indicated that general heuristics did not transfer well to new situations.

Schoenfeld's own small-scale research study conducted at Berkeley in 1977-78 showed that students could learn to use some heuristic strategies. However, Schoenfeld said the students in his study had extensive backgrounds in math and had already mastered the skills required to apply the heuristic techniques and had probably solved many problems using those skills prior to the study (Schoenfeld, 1985).

Although he questioned its effectiveness, Schoenfeld (1985) did believe that the mention of the heuristic technique served to bring those skills to the students' conscious attention and helped them access those skills and use them more readily.

Prior to 1968, most research on mathematical problem solving concentrated on more effective classroom methods of teaching. However, in 1968, things changed after the following three events took place: (a) Jeremy Kilpatrick researched and wrote a thesis on problem solving, (b) new information was developed about artificial intelligence, and (c) the psychology of information processing emerged. The new theories and thesis by Kilpatrick changed the focus of research in mathematical problem solving.

In his research, Kilpatrick (1969) studied the mental processes that students used in solving the problem instead of just focusing on the solution as most of his predecessors did. He noted that "since the solution of a problem is typically a poor index of the processes used to arrive at the solution problem solving processes must be studied by getting subjects to generate observable sequences of behavior" (p. 526). Kilpatrick, therefore, interviewed each of his students while they solved the problem so he could see how their minds worked.

In addition to his thesis, Kilpatrick (1969) also added to the literature base by conducting a comprehensive review of studies which concerned problem solving that were published between 1964 and 1969. Kilpatrick divided the studies into categories that included the following: Problem solving ability, problem solving tasks, problem solving processes, instructional programs and teacher influence.

Larkin (in Nickerson, 1985) added to the growing literature base by studying information from the work in the area of artificial intelligence. Larkin identified three general problem solving strategies that appeared repeatedly in computer programs that were useful in solving logic and arithmetic puzzles and in some aspects of playing chess. The strategies programmed into computers were similar to those that Polya taught humans to use and included the following (in Nickerson, 1985):

1) Means-end analysis - this involves determining the difference between the current state of knowledge about a problem and the state required to produce a solution and selecting some action that will reduce the difference between these two states.

2) Planning - this involves replacing the original problem with a simpler version, solving it and using its solution to guide the search for a solution to the original problem.

3) Use of sub-goals - this involves the replacing of temporarily unattainable goals with simpler sub-goals.

Nickerson (1985) supported the views of Polya and Wallas and liked the idea of teaching general problem solving strategies. Nickerson (1985) said that heuristics seemed to be worthy of teaching because of the following reasons. (a) Since they are clear enough to be programmed in a computer they should be communicable to students, (b) the commonly accepted heuristics are the ones expert problem solvers really do use, and (c) there are few enough heuristics to make it feasible to teach them.

Characteristics of Problem Solvers

Nickerson (1985) believed two types of expertise are used in problem solving. The first kind is the expertise that is based on knowing a lot about a subject area. This is known as domain-specific knowledge. The second type of problem solving relates to the ability to manage one's intellectual resources and to use whatever domain-specific knowledge one has most effectively.

Schoenfeld emphasized the second type of expertise and said expert problem solver are better problem solvers because they are better at managing their resources (in Nickerson, 1985).

In addition, Schoenfeld suggested that the quality and success of problem solving are also very much dependent on the presence or absence of effective management behavior. "Experts are more likely to conduct an 'executive review' of a process in which they are engaged perhaps especially when the process seems to be getting bogged down" (in Nickerson, 1985 p. 69). It appeared that experts have monitors that trigger such reviews, whereas novices do not.

However, as Rosemary Schmalz (1989) pointed out, if none of the strategies work, students often experience a loss of what to do. Polya suggested that one sit tight till they get a bright idea. This sudden presence of new insight is known as a breakthrough.

Schmalz reported that Henri Poincare (1929), Jacques Hadamard (1949), and Noddings and Shore (1984) all agreed that there are some ways of sitting and waiting which are more productive than others. Schmalz called these more productive ways a problem solving attitude. This attitude consists of confidence in using mathematics, flexibility, willingness to persevere, interest, curiosity, inventiveness concerning mathematics, and the ability to monitor and reflect upon one's own thinking and performance.

For the most part, math students have not needed to use much flexibility in solving problems. The tasks they are assigned need only the most recently presented strategy in order to solve them. Textbooks frequently present a few "story problems" that use the mathematical operation taught on that page.

Suydam (1980) summarized research findings to determine characteristics of good problem solvers. She found that they tended to have relatively high IQ scores and reasoning ability, high reading comprehension scores, high quantitative ability or computation scores for success in numerical problems, and high spatial aptitude scores for success on geometric problems (in Krulik & Reys, 1980). In addition, Suydam found that positive attitudes toward mathematics and lack of concern about messiness or neatness contribute to the successfulness of the student.

Marshall (in Charles & Silver, 1988) characterized a person as a good or poor problem solver according to the extent that he/she could be placed in a novel experience and use previously known information to make sense of the new experience. Marshall said good problem solvers can recognize important similarities and differences between the novel situation and other already encountered problems, have several response options available to them and know when and how to acquire more information if it is necessary. Suydam (1980) found that good problem solvers take more time to solve novel problems than poor problem solvers do (in Krulik & Reys, 1980).

Variables in the Problem Solving Process

In the 1970's and early 80's, the research focused on the variables involved in the problem solving process. Three groups of variables seemed to exist.

1. Task Variables-the factors that make problems difficult or easy such as content, format, context, or logical structure.
2. Subject Variables-the factors that affect problem solving achievement such as previous knowledge, cognitive style and attitude.
3. Instructional Variables-the factors that make up the school experiences that are intended to develop problem solving skills.

Maier (1970) suggested reasons that make solving problems difficult. One involves misleading incorrect solutions. This is when a person arrives at an incorrect solution but fails to realize it and stops further effort.

Another reason is difficulty in choosing between given alternatives. The examiner's selection of incorrect response choices can make this more or less difficult for the subject depending on how realistic he/she makes the other choices.

Summary

The area of problem solving is becoming one in which students will have to think and reason not merely apply newly taught operations to key words or numbers as they have done so frequently in the past. Educators are beginning to realize the importance of problem solving instruction and the active role it takes in the workplace. Much has been learned about the problem solving process, characteristics of good problem solvers, and strategies which can be taught to students. A large part of problem solving instruction focuses on a student's ability to apply previously learned concepts to novel situations. Therefore, it follows that teachers must also become aware of the nature of transfer of learning. Educators must learn instructional strategies that will help to ensure that transfer takes place.

Definitions and Viewpoints of Transfer of Learning

Ellis (1965) says transfer of learning refers to the influence an experience or performance on one task has on the performance of some subsequent task.

According to Mayer (1977), the Gestalt psychologists believed that two kinds of thinking exist. One is called productive thinking because a new solution to a problem is created. The second type is labeled reproductive thinking and is similar to Ellis's view of transfer. Gestalt psychologists call it reproductive thinking because it is based on applying past solutions to a problem or reproducing old habits and behaviors.

Transfer of learning can be positive,negative, or have no effect on subsequent performance. Positive transfer takes place when prior learning **facilitates** subsequent task performance or learning. Negative transfer occurs when previous learning **interferes** with later learning. Zero transfer occurs either as a result of **no effect** of one task on another or as a result of equal effects of positive and negative transfer that cancel each other out (Ellis, 1965).

Gagné and Driscoll (1988) further distinguished both negative and positive transfer of learning into lateral and vertical transfer. Lateral transfer refers to the influence of prior learning of a task on the learning of another task at **similar levels of difficulty.** It can also mean the use of prior learning in new situations different from the situation in which the original learning took place. Gagné and Driscoll (1988) say lateral transfer depends upon the effectiveness of memory search and retrieval carried out by the learner when he confronts new situations to which his previously learned capabilities must be applied. Vertical transfer is the influence of prior learning on the learning of **more complex tasks** that require higher level skills.

Hunter (1971) believes "transfer is the heart and core of problem solving, creative thinking and all other higher mental processes as well as inventions and artistic products" (p. 2). Hunter (1971) also suggests that transfer of learning provides a source of real economy of time and energy because as previous learning facilitates new learning, such transfer of learning can effectively decrease the time needed to achieve any new learning.

Early Theories of Transfer of Learning and Education

Over the decades, educators have continued to teach certain school subjects not so much for their inherent value but, rather, for their use in facilitating other learning. An important objective of education was the study of specific subjects in order that the study would "discipline" the mind. This was especially true of mathematics and Latin as they were thought to strengthen reasoning and memory. Lately, mathematics, logic and computer programming are among those subjects taught for this purpose (Resnick, 1987).

The practice of teaching subjects in order to facilitate other learning is a result of the long-held view known as the doctrine of formal discipline. This view held that the mind was composed of several faculties such as reasoning, memory, judgement, and attention and that these faculties could be trained and improved through the study of certain kinds of subject matter.

However, in 1901, Thorndike and Woodworth examined the views of formal discipline and did not find any substantial evidence to support it. They looked at transfer among school subjects and found that it was more efficient to study the subject of interest than some other subject that prepared one's mind. Subsequent reviews of research on transfer have reconfirmed Thorndike and Woodworth's findings (in Resnick, 1987).

As a result of the findings, educators gradually gave up the formal discipline viewpoint and taught subjects because they were important in their own right.

Theory of identical elements:

Thorndike and Woodworth (1901) also concluded that transfer of learning is limited to those situations in which the two tasks contain identical elements. Training in one kind of activity will transfer to another as long as certain features such as aims, methods, and approaches are identical in the two tasks (in Ellis, 1965).

Generalization or working rule theory:

The theory of identical elements was challenged as a result of studies by Judd in 1908 (in Gagné and Driscoll, 1988). Judd reported that the most important factor in producing transfer was that the student be able to abstract a general rule or principle to follow. This was known as the theory of generalization. It meant that a student could generalize his experiences from one situation and apply them to another. The guiding principle could function as a retrieval cue to connect the principle to the new context.

In order for transfer to occur, the generalization theory suggested that the student be taught to think about those features of a problem that might be generalized to new situations. The generalization theory showed that transfer was not an automatic process and that students must be given practice in transfer.

Transfer of Learning in Mathematics

There is no general agreement about the extent to which lateral transfer can take place in mathematics. Some psychologists and learning theorists believe broad transfer can take place within a discipline and even outside it. Other psychologists believe that transfer occurs to a very limited extent usually only if identical elements occur. (Orton, 1987)

Kantowski (1981) said experience in solving nonroutine problems can help students transfer methods of problem solving to new situations. Kantowski also suggested that educators develop sets of related problems because students learn by solving similar kinds of problems (in Fennema, 1981).

Kantowski continued and mentioned several processes which appear to be important in solving nonroutine problems.

1) The Solution Set-Up - this refers to a variety of manipulations of data that could lead to a solution.

2) Planning - this is when the problem solver tries to find a relation to other problems solved previously and decides on a method of solution to try to follow.

3) Transfer - this is the memory for and application of

methods used in previously solved related problems.

Factors Which Affect Transfer of Learning

1. Intelligence:

Ellis (1965) said many studies investigated the role of intelligence on transfer and found that the more intelligent students show greater amounts of transfer. Brighter students tend to seek out relationships and are more likely to have a set for transfer than do the less bright students.

2. Similarity of tasks:

Ellis (1965) conducted a study in 1958 in which he investigated the effect of similarity on transfer. The results showed that the greater the degree of similarity between tasks, the greater the amount of positive transfer.

Treffinger and Ripple (1968) reported similar findings after they investigated the effectiveness of Covington and Crutchfield's General Problem Solving Program and its impact on nonspecific transfer. The researchers tested students in the fourth to seventh grades. The results suggested that the General Problem Solving Program may be successful in promoting some transfer to novel problems but unless the format of the problem resembles that of the training materials, transfer is likely to be minimal (in Kilpatrick, 1969).

A slightly different result was found in a research study in which the researchers reported that students were unable to transfer information between similar problem situations unless the second problem was easier than the first. They also found that transfer occurred only when subjects were specifically told that the problems were similar (Reed, Ernst, and Banerji Krulik & Reys, 1980).

3. Elapsed time between tasks:

Ellis (1965) reported many studies (Bunch, 1936, Bunch & McCravey 1938, Bunch & Lang, 1939) which indicated that transfer or training remains roughly constant with varying intervals of time elapsing between the original and transfer tasks. In other words, it doesn't matter if the time interval between tasks is one day or several weeks. The only instance in which the amount of time elapsed affected performance was when performance on the transfer task depended on memory for specific items.

4. Amount of practice and variety of original task:

Thorndike, a leading Associationist, believed that responses which are previously practiced many times with a given situation are more likely to occur when that situation is presented again. He termed this the law of exercise (in Mayer, 1977).

Ellis (1965) also revealed a general rule that positive transfer increases with increasing practice on the original task. Positive transfer also increases with an increased variety of original training. It was found to be better to practice with a variety of related tasks rather than extensively on a single task.

5. Enjoyment of original learning condition:

Skills acquired under enjoyable learning conditions were usually retained for long periods of time whereas skills acquired under unpleasant learning conditions were usually forgotten after a short-term goal had been reached such as completion of homework assignments, tests, and final examinations (Gallagher, in Krulik & Reys, 1980).

Classroom Practices and Negative Transfer Effects

Students often learn to rely on procedures and give up on common sense. Students can quote the steps involved in division or recite multiplication rules but often don't have any idea whether their answers are reasonable. This can lead to the finding of ridiculous answers.

The following problem was given to students on the third National Assessment of Educational Progress (Schoenfeld in Silver, 1988):

"An army bus holds 36 soldiers. If 1128 soldiers are being bussed to their training site, how many buses are needed?"

29 percent of the students who worked the problem gave the answer of "31 remainder 12", even though the question asked how many buses were required.

To obtain this answer a student had to suspend the sense-making requirement. Schoenfeld (in Silver, 1988) believes that the students who obtained this answer did so by implementing a four-step procedure that consisted of the following: 1) read the problem; 2) select the numbers and relevant operation; 3) perform the operation; and 4) write down the answer. This method was derived from classroom practice and was rewarded in the classroom context.

Schoenfeld further related an example given by Paul Cobb in a research session at the 1984 National Council of Teachers of Mathematics annual meeting.

Cobb asked students from four schools to solve a worksheet of simple equations that listed problems like "9 - X = 6", "X - 5 = 7", and "8 = X - 3" in an order similar to this. Almost all of the tested students from one of the schools made the same errors. They usually got the first problem right but many of the others wrong. When their classroom was visited by the researcher, it was found that they were given daily worksheets which contained problems of all one format such as "9 - X = 6", "10 - X = 4", etc.

The students figured out how to solve the first problem and then applied that procedure to all of the remaining problems. This incident demonstrates that student problem solving behavior is shaped by the day-to-day classroom rituals in which they engage and can interfere with transfer of learning (Schoenfeld in Silver, 1988).

One learns in classroom practice to combine the numbers whether or not doing so makes sense in other contexts. Mathematics instruction generally provides support for the idea that students need not try to make sense of problems. Students often use a "key word" algorithm to solve problems without reading them (Schoenfeld in Silver, 1988).

Bartlett (1958) also observed the negative transfer effect in mathematics. He studied his subjects' attempts to solve the following mathematical problem (in Mayer, 1977).

	D O N A L D	Given: D = 5
+	G E R A L D	Every number 0-9 has a corresponding letter.
	R O B E R T	Find a number for each letter.

Bartlett (in Mayer, 1977) believed that much of the difficulty subjects had in solving this problem was due to their past methods of solving addition problems by working from right to left. The students substituted 5 for D and 0 for T, but couldn't get any farther since there were no direct clues for the letters L and R.

Duncker (1945) viewed negative transfer in a slightly different light. He said that when prior experience had negative effects on certain new problem solving situations, it was probably due to functional fixedness. Duncker defined functional fixedness as the "inhibition in discovering an appropriate new use of an object owing to the subject's previous use of the object in a function dissimilar to that required by the present situation" (in Mayer , 1977 p. 77).

Duncker designed a series of problems to test his theory of functional fixedness in the laboratory. One of his problems involved giving subjects candles, thumb tacks, and a box of matches. The subjects were then asked to mount the candle vertically on a nearby screen to serve as a lamp. The solution required the subjects to empty one of the container boxes, use it as a candle holder, and attach it to the screen instead of trying to attach the candle. Duncker found that students had a greater success rate when the materials were placed next to the boxes instead of inside them. Duncker found that the placement of objects inside a box fixed its function as a container thereby making it more difficult for the subjects to reformulate the function of the box and think of it as a support (in Mayer, 1977).

Adamson (1952) reran Duncker's box problem with a larger population (57 subjects instead of 14). Adamson found that 86 percent of the subjects solved the problem within twenty minutes when the boxes were presented empty as compared to only 41 percent who solved it when the boxes were presented as containers (in Mayer, 1977).

Another example of functional fixedness was demonstrated in 1970 in Maier's classic Two-String Problem. In the experiment, Maier asked subjects to connect two ropes that were hanging at near opposite ends of a room and were too short to reach each other. The ropes could be connected if an additional item was attached to the other and used as a pendulum. Maier had a ruler, twine, a weight, and soap available for the subjects' use if desired. For the most part, Maier found that the dominant functional value of a tool influenced the type of solution reached.

Teaching for Transfer

Even though a skill learned in one context may in principle apply to another, often a person who has mastered the skill in the first context does not think to apply it in the second. In addition, many skills acquired in one context do not carry straight over to others, but require significant adjustment (Nickerson, 1985).

Therefore, Nickerson (1985) believed one should teach in order for transfer to occur. Instruction can explicitly encourage students to carry over the skills to other contexts. Exercises can provide practice in making connections to remote contexts. The teacher can teach principles in general, context-free forms that facilitate transfer.

Gagné and Driscoll (1988) similarly believed that teaching for transfer meant providing learners with processes for retrieval that will apply in many kinds of practical contexts.

Ellis (1965) presented the following guidelines for teaching so that what is taught is more likely to transfer to new learning situations. The guidelines are derived from the results of research studies and the dominant theories about transfer.

1. Maximize the similarity between teaching and the ultimate testing situation.

2. Provide adequate experience with the original task.

3. Provide for a variety of examples when teaching concepts and principles.

4. Label or identify important features of a task.
5. Make sure that general principles are understood before expecting much transfer.

Hunter (1971) agreed with the others and said that significant and efficient transfer predictably occurs only if we teach to achieve it.

In sum, if educators want to see previously taught skills applied to new problems and contexts, they must set their instruction to encourage this type of transfer. It is generally believed that transfer of learning does not occur as easily or as automatically as once thought.

Therefore, teachers of problem solving need to make a special point of identifying guiding principles, similarities between problems, and providing students with a wide variety of enjoyable problem solving situations so that transfer can occur more frequently and routinely. Keeping this finding in mind, the role Odyssey of the Mind plays in transfer of problem solving skills seems worthy of investigation.

CHAPTER III

METHOD

In an attempt to fully describe the methods and procedures used in the study, this chapter begins with a list of the null hypotheses which were tested. A description of the sample follows along with a summary of findings from a pilot study which were used to formulate the design of the dependent measure. The chapter concludes with a description of the test instrument, research design, and the procedures used for collecting the data.

Null Hypotheses

The following null hypotheses were tested:

1. There is no difference in the problem solving achievement scores across the gifted and non-gifted groups.

2. There is no difference in the problem solving achievement scores between the experimental (Odyssey of the Mind participants) and the control group subjects (non-Odyssey of the Mind participants).

3. There is no difference in the problem solving achievement scores across genders.

4. There is no difference in the problem solving achievement scores on test question #5 across OM and non-OM groups.

5. There is no relationship between the problem solving achievement scores and the number of years of OM experience.

6. There is no relationship between the problem solving achievement scores and the success levels of OM participants.

7. There is no difference in the problem solving ratings given by teachers between the experimental and control group subjects.

8. There is no difference in the self-ratings for problem solving ability between the experimental and control group subjects.

Sample

The students for the study were selected from among the schools in Illinois who 1) had competed in Illinois' Odyssey of the Mind regional competition in 1990 in Division II (grades 6-8); 2) had indicated their willingness to participate; and, 3) had seventh graders as part of the student population. It should be noted that only one grade level (7th) was used in an attempt to control for extraneous subject variance that might have influenced the experimental outcomes of the study.

Four of the selected schools were located in the far north/northwestern suburban regions of Illinois. Two of the schools were located in suburbs just west of Chicago and one school was situated in the southern tip of Illinois. (See Table 1 for the breakdown of participants in the original sample).

TABLE 1

Breakdown of Participants in Original Sample

School	Gifted/OM	Non-Gifted/OM	Gifted/ Non-OM	NonGifted/ Non-OM	Total
	N	N	N	N	N
North/Northwest Suburban Schools:					
A	11	3	12	14	40
B	6	25	1	28	60
C	18	4	15	21	58
D	20	15	55	83	173
West Suburban Schools:					
E	6	0	38	0	44
F	10	9	9	39	67
Southern Illinois School:					
G	8	1	25	4	38
Total	79	57	155	189	480

The experimental group consisted of one hundred students who were randomly selected from the initial sample cluster of 136 OM participants. These 100 students were further broken down into two sub-groups depending on whether they had (N=50) or had not (N=50) been identified as being gifted in math. In addition, the control group consisted of one hundred students who were randomly selected from the initial sample cluster of 344 students who had never participated in the Odyssey of the Mind Program. The ability levels of the students in the control sample were assumed to be comparable to the experimental sample students since both groups were selected from the same math classes. The control sample students were also divided into two sub-groups of 50 each depending on whether they had been identified as gifted in math.

The final sample consisted of the following numbers and groups:

	OM	Non-OM
Gifted	N=50	N=50
Non-gifted	N=50	N=50

Refer to Table 2 for a detailed breakdown of participants selected for inclusion in the final sample.

TABLE 2

Breakdown of Participants in Final Sample

School	Gifted/OM N	Non-Gifted/OM N	Gifted/ Non-OM N	NonGifted/ Non-OM N	Total N
North/Northwest Suburban Schools:					
A	5	2	5	2	14
B	6	24	1	24	55
C	10	0	10	3	23
D	10	15	15	11	51
West Suburban Schools:					
E	6	0	6	0	12
F	9	8	9	10	36
Southern Illinois School:					
G	4	1	4	1	10
Total	50	50	50	50	200

Description of the Pilot Study

A pilot problem solving test was administered to volunteer students at the 1990 OM World Finals (n = 50). From an examination of the pilot test results, a decision was made to design the study in the following three ways:

1. Grade Level

Seventh grade students became the targeted population of the study. The investigator had originally planned to use sixth grade students in the study. However, given the results related to the pilot data set, it was determined that younger students appeared to be very limited with respect to their problem solving ability(ies). This limitation seemed to be a function of the students' very limited exposure to mathematical concepts. For example, one of the problems (dropped from the final form of the problem solving test) asked students to solve an equation that featured Roman Numerals. Several sixth grade students wrote on their test or told the examiner they couldn't do the problem because they didn't know Roman Numerals.

2. Test Length

The test instrument was shortened to five questions in the final version. From the pilot results it was determined that ten questions were too many for the majority of students to complete in a timely manner. The students seemed to tire after five questions and many stopped working the problems after this point.

3. Focus of Test

The overall nature of the test instrument was altered somewhat. In the pilot study, the test consisted of "brain-teaser" problems. Many of the tasks required the students to find a "catch" in the problem in order to solve them. The final version of the problem solving test was designed to let students apply previous math or problem solving instruction to new situations. The new test instrument consisted of released items from the 1986 National Assessment of Educational Progress (NAEP) exam.

Procedures

A letter and interest survey was sent to OM contact persons at 22 different schools. Twelve surveys were returned to the researcher. Seven of the twelve schools that returned their surveys met all of the selection qualifications and were contacted by telephone. The seven schools were then sent copies of the test instrument with scripted instructions for administering it. In addition, teachers also received a guide for rating student problem solving ability. (See Appendix A). Teachers were instructed to use this guide to rate each student on a scale from one (very good problem solving ability) to five (very poor problem solving ability) in an effort to document the amount of problem solving ability the teachers thought each student had. Teachers in each of the schools gave the tests to seventh grade students who had participated in Odyssey of the Mind (N=136) and to non-OM participants (N=344) enrolled in the same math classes as the OM participants. A total of 480 completed test instruments were returned. (See Table 1).

Problem Solving Instrument

Problem solving achievement was assessed using a five-item test that consisted of both multiple choice and open-ended questions. Three of the problem solving items were selected from the released problems that were actually used in NAEP's 1986 assessment for seventh grade students.

Five elements were considered in choosing each of the problem solving items. First, it was desired that the problems come from a reliable source that could provide statistical data on the success rate of the problem. Second, the problems needed to be "classical" in nature. They had to be fairly typical of the types of problems students may have been asked to solve in the past. Third, the students could not be required to need anything other than paper and pencil in order to solve the problems. Fourth, the problems could not require the students to need a memorized rule such as "Length × Width = Area" in order to solve them. Lastly, the problems had to be nonroutine and ask the students to combine previously learned elements of knowledge to novel situations.

In addition to the above-listed criteria, the problem solving test was designed to require no more than about thirty minutes to complete.

The first selected problem served as a warm-up and confidence-building task. It had the highest success rate (38.1%) of the three problems that were taken from NAEP's released items. The problem asked students the following:

> Dawn has 3 skirts and 5 blouses. How many different skirt-blouse outfits can she make with these?
>
> - 3
> - 5
> - 8
> - 15

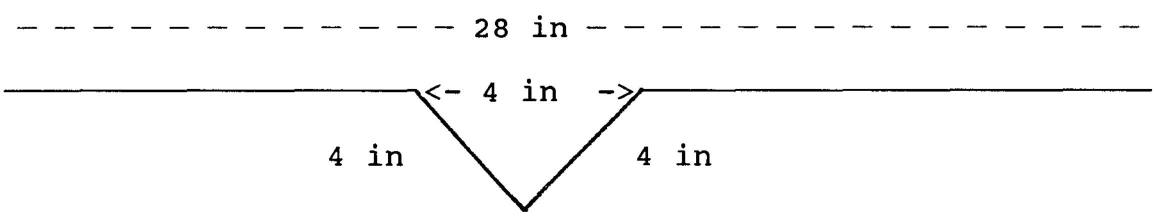
According to NAEP, the problem's content involved discrete mathematics and required the student to use a routine application in order to solve it. If students had been taught how to solve "combination" type problems, they could apply a previously learned rule such as multiplying the number of choices in the problem in order to get the total. The question could also be solved by students who had never been taught this kind of problem. Students could use common sense and rule out at least two of the answers (3 and 5). They could also rely on a strategy such as drawing a picture to show the various possibilities.

The second problem had a reported success rate of 20.9% and was considered to be at a Level 350 by NAEP. "Students performing at Level 350 demonstrate the capacity to apply mathematical operations in a variety of problem settings." (Dossey et al; 1988 p. 42) NAEP reported that less than one half of 1% of the 13 year olds reached this proficiency level. The problem asked students the following:

> Suppose you have 10 coins and have at least one each of a quarter, a dime, a nickel, and a penny. What is the <u>least</u> amount of money you could have?
>
> 41¢
>
> 47¢
>
> 50¢
>
> 82¢

NAEP reported that the problem's content involved measurement and required the students to use problem solving and reasoning skills in order to solve it. It was a fairly straight forward question, but students had to read it carefully for the stated conditions such as 10 coins and finding the least amount of money.

The third problem had the lowest success rate (9.7%) of the three NAEP items that were used. It asked the following:



What is the length of the solid line?

ANSWER________inches

NAEP reported that the task involved measurement and required the students to use their problem solving and reasoning skills in order to solve it. It was a different type of measurement problem than the first problem since the first one dealt with money and this one involved linear measurement.

The fourth question was taken from Marcy Cook's (1989) idea section in *Arithmetic Teacher* and was also used as part of a testing instrument by researchers at Loyola University in 1989. The problem was given to students whose teachers participated in a Math Curriculum Improvement Project (Jagielski, 1989). The problem was as follows:

> House numbers can be made with the numbers 0, 1, 2, 3, 4, 5, 6, 7 , 8, or 9. My house number has three different digits. The sum of the three digits is 6. The number does not begin with 0. What could my house number be? List all the possible numbers.

The problem required students to use problem solving skills and pay close attention to the conditions of the problem. The task was easier to solve if the students used a problem solving strategy such as looking for patterns or establishing an organized list. The problem was not a difficult one, but could be hard to solve because of its open-endedness and no choice of possible solutions. It could be difficult for some students to generate all of the possible solutions.

The fifth problem was adapted from a classical creative problem solving study first conducted by Duncker in 1945. This problem was previously discussed in Chapter Two and asked that the problem solver attach a candle to a wall. Students could use the available materials; a box of matches and a box of tacks to help them solve the task.

Duncker said the most effective solution to the problem (using the match or tack box as a platform or holder for the candle) was infrequent because subjects were "fixated" on the use of the box as a container for the fasteners and therefore were not able to conceive of the box as a platform for the candle.

An adaptation of the candle problem was included in the test instrument because it matched one of the areas of emphasis in OM, that of using ordinary objects in different ways. It was interesting to see if students who had participated in the Odyssey of the Mind Program had a higher success rate on this problem than non-OM participants.

Design

The overall research design was an experimental six-group post test only design. Since the treatment had already taken place and could not be controlled by the researcher, randomized selection of subjects from a cluster of available subjects was used in an effort to help control for individual differences. Students were selected at random from more than one classroom and more than one school for each cell. By obtaining a cross-section of students throughout the system, the generalizability of results would not be limited to a particular school, a particular ethnic background or only one socio-economic background. Randomization would also help to maximize the representativeness of the educational sample and to help ensure equivalence across groups. In addition, randomization would also help to control extraneous variables or effects of contemporary history, maturation (events taking place between the time the treatment occurred and the time the post test was given), and differential bias with respect to the selection of subjects.

A 2 × 2 × 2 factorial design was used so that several hypotheses could be tested simultaneously and to determine if interaction between two or more variables made a difference.

Overall, the study consisted of three major independent variables; each varied two ways. Four additional independent variables related to the OM participants were also examined. The first independent variable pertained to giftedness. The students were grouped according to whether or not they had been identified as being gifted in math. It should be noted that the method of identifying students as gifted in math varied between school districts. For the most part, however, students were identified as being gifted if they scored 95% or higher in the math subsections on a standardized test. The second independent variable was participation in OM. The subjects were classified as either having experience in the OM Program or not having experience with OM. Participation was generally defined as involvement with a team and having worked on a solution to a long-term problem. The third independent variable was the gender of the subject. Gender was assigned as either male or female.

An additional independent variable included the number of years a student participated in Odyssey of the Mind. The number of years depended on the grade level in which the students' school began OM. Since some school districts in the study began OM in the third grade, students could have one to five years experience by the time they took the post test.

Another independent variable was that of the success level attained by the OM participant. The success level referred to the highest arena of competition in which the student competed. The lowest level meant competing only in the student's school district. The next level was a regional competition which meant competing against an average of eight teams from other school districts in a team's region. The second highest level was the state contest which was arrived at only after winning first or second place in a student's region. The top level was world finals which was attended by the winning teams from each state and participating country.

A third independent variable was the type of problem on which the OM participant most liked to work. The four types of problems from which students could choose consisted of those involving drama, technology, structure (engineering), and a combination problem using art and science skills. A final independent variable was if the OM participants believed Odyssey of the Mind helped them to become better problem solvers.

Crosstabulation procedures, factorial analyses of variance (ANOVA), and regression analyses were used to test the eight null hypotheses listed on pages 50-51. The main analytic paradigm consisted of a 2 X 2 x 2 factorial design:

	Gifted		Non-gifted	
	Male	Female	Male	Female
OM		P r o b l e m	s o l v i n g	
Non-OM		a c h i e v e m e n t	s c o r e s	

CHAPTER IV

RESULTS

The purpose of this study was to determine if participation in the Odyssey of the Mind Program could help students to become better problem solvers. The study was designed to address the question of the extent to which differing levels of participation in OM influences a student's problem solving ability.

This chapter is divided into four main sections. A descriptive analysis of the final sample is presented in the first section. Tables of means for the test instrument are reported and discussed in the second section. The results related to each of the hypotheses tested are examined in the third section of the chapter. The data results was analyzed using a combination of analyses of variance, crosstabulations, chi square analyses, and regression analyses procedures. The final section of the chapter provides a more fine grained examination of the relationship between the independent and dependent variables.

Descriptive Examination of the Final Sample Responses

As stated earlier, the descriptive variables examined in the study included sex, the number of years a student participated in Odyssey of the Mind, the farthest level of OM competition reached by the participant, the type of problem on which the OM participant most liked to work, and if the participants believed OM helped them to become better problem solvers. The frequencies of these descriptive variables are illustrated in Tables 3 - 6.

An examination of Table 3 indicates that the males and females were fairly evenly split in the study. Approximately fifty-five percent of the population were female and about forty-six percent were males.

TABLE 3

Frequency Distribution of Subjects by Sex

Sex	N	Relative Frequency %
Females	109	54.5
Males	91	45.5

Total N = 200

The results reported in Table 4 indicate that seventy-two percent of the OM population participated in the program for two years or less. The majority of this sub-group (58%) had been involved with Odyssey of the Mind for only one year. Fourteen percent of the participants had two years of experience with OM and three percent had participated for three years. One participant had worked with Odyssey of the Mind for five years, the maximum amount of time OM was offered to students in any of the school districts included in this study.

TABLE 4

Frequency Distribution of Number of Years in OM

Number of Years	N	Relative Frequency %
0	100	50
1	58	29
2	14	7
3	24	12
4	3	1.5
5	1	.5

X = 1.75 SD = .99 Total N = 200

Table 5 shows that of the 100 Odyssey of the Mind participants included in the study, the largest number (44%) competed at the regional level. One-fifth of the OM participants won at the regional level and competed in the Illinois State Finals. Nineteen percent of the OM participants won at both the regional and state levels and represented Illinois at the World Finals. The fewest number of OM respondents (17%) were involved at the local level only and did not compete with schools from other districts.

TABLE 5

Frequency Distribution of Subjects by Level of OM Competition

Competition Level	N	Relative Frequency %
School District	17	17
Regional	44	44
State Finals	20	20
World Finals	19	19

Total N = 100

The results reported in Table 6 indicate that forty-two percent of the OM participants liked to work on drama-type problems. This type of problem required students to write scripts and produce plays with costumes and scenery. Twenty-one percent of the OM students liked to be involved in a problem that used both art and science. An example of this type of problem was one called Omnitronic Humor which required the students to build a robot that then acted in a play written by the team. Twenty percent of the OM participants preferred working on a problem that involved science and technology. These types of problems generally required students to build battery-operated vehicles, use electricity or apply knowledge of physics. Seventeen percent of the OM participants liked working on a structure-type problem. This type of problem required the students to build a light-weight structure out of balsa-wood that could hold large amounts of weight.

TABLE 6

Frequency Distribution of Subjects by Type of Preferred OM Problem

Type of OM Problem	N	Relative Frequency %
Drama	42	42
Combination (arts/science)	21	21
Technology	20	20
Structure	17	17

Total N = 100

Finally, it should be noted that 85% of the OM participants believed that participation in Odyssey of the Mind helped them to become better problem solvers.

Results of the Test Instrument

The major dependent variable used in this study was the measure of student problem solving ability. One way this was assessed was through the use of the five-item test previously discussed in Chapter Three. The problem solving ability test instrument included three tasks (items 1-3) which were chosen from released problems of the National Assessment of Educational Progress's (NAEP) 1986 assessment for seventh grade students. An additional problem (item 4) came from Arithmetic Teacher (Cook, 1989) and was also used as part of a testing instrument for a research project at Loyola University

(Jagielski, 1989). The final task (item 5) was adapted from a classical creative problem solving study originally conducted by Duncker in 1945.

The frequencies, means, and standard deviations of the responses to the test instrument for the experimental and control groups are presented in Tables 7-12. The results were examined by individual items and by total score. Also, in the case of test items one through three, the experimental and control population's scores were compared to the seventh grade group's scores who took the 1986 NAEP assessment.

As shown in Table 7, the three items from NAEP's assessment were solved correctly more often than the other items on the test. Problem solving item one was solved correctly by the largest number of respondents (87%) whereas item four had the fewest (8.5%) number of students who correctly answered it.

TABLE 7

Frequency Distribution of Test Scores by Item

Question	N	Relative Frequency %
1	174	87
2	137	68.5
3	106	53
4	17	8.5
5	44	22

Table 8 illustrates the comparison to the results from the NAEP's 1986 assessment. A much higher percentage of students in the study reported here successfully solved the three NAEP items than did those in NAEP's 1986 sample. More than twice the number of NAEP's respondents (87% as compared to 38.1%) correctly answered item two and approximately five and one half times the number of students in NAEP's sample (53% as compared to 9.7%) solved item three. Tests for equality of proportions indicated that there was a significant difference between the NAEP's sample and the sample used here ($p < .01$) for each of the three NAEP items. Thus, the participants in the study reported here were well above the level of national proficiency described in the 1986 NAEP assessment.

TABLE 8

Comparison of NAEP Scores to OM Study by Percent of Correct Response

Test Item	NAEP	OM Study
1	38.1	87
2	20	68.5
3	9.7	53

Results Related to Testing Null Hypotheses #1 - 3

To test Hypotheses One through Three, a 2 x 2 x 2 factorial analysis of variance was used with the score from the problem solving ability test instrument being the continuous dependent variable and sex, giftedness, and participation in Odyssey of the Mind being the independent variables. A summary of results is presented in Tables 9-12.

When the problem solving ability test was examined as a whole, the mean score was 2.39 (out of a possible 5.0) and the standard deviation was 1.07. The largest number of respondents (36%) received a score of 3.0. Only 1.5 percent of the population earned a perfect score on the test. The distribution of scores appears to form a fairly normal curve. (See Table 9).

TABLE 9

Frequency Distribution of Test Scores by Total Score

Total Score	N	Relative Frequency %
0	7	3.5
1	32	16
2	64	32
3	73	36
4	21	10
5	3	1.5

X = 2.39 SD = 1.07 N = 200

Table 10 reports the various means when the test was reviewed in respect to groups of sex, giftedness and treatment. Males (x = 2.59) scored higher than females (x = 2.22). The gifted students (x = 2.77) scored higher than those who were not gifted (x = 2.01) and Odyssey of the Mind participants (x = 2.65) outscored those students who had never participated in the program (x = 2.13).

TABLE 10

Test Means by Sex, Giftedness and Treatment

Group	N	X
Sex		
Females	109	2.22
Males	91	2.59
Giftedness		
Gifted	100	2.77
Non-Gifted	100	2.01
Treatment		
OM Participant	100	2.65
Non-OM Participant	100	2.13

Total Population X = 2.39 SD = 1.07

Table 11 indicates that in all cases, students who participated in Odyssey of the Mind scored higher than their non-participating counterparts. The only time participation in OM did not have a higher mean than any sub-group in the study was when giftedness was involved. Students who did not participate in OM but who were gifted (x = 2.52) had a higher mean than the OM participants who were not gifted (x = 2.28). The gifted males who participated in Odyssey of the Mind (x = 3.14) scored the highest of all the respondents.

TABLE 11

Test Means by OM Participation, Sex and Giftedness

	OM Participants		Non-OM Participants	
	N	X	N	X
Male	43	2.81	48	2.40
Female	57	2.53	52	1.88
Gifted	50	3.02	50	2.52
Non-Gifted	50	2.28	50	1.74
Gifted/Male	22	3.14	26	2.77
Non-gifted/male	21	2.48	22	1.95
Gifted Female	28	2.93	24	2.25
Non-gifted/Female	29	2.14	28	1.57

Total Population X = 2.39 SD = 1.07

The first null hypothesis stated that there would be no significant difference in the problem solving achievement scores across gifted and non-gifted groups. The analysis of variance (ANOVA) indicated there were no significant two or three-way interactions. However, there were significant differences for the main effects across gifted and non-gifted groups ($F = 32.122$, $p<.01$). The students who were identified as gifted ($X = 2.77$) scored significantly higher than those who were not gifted ($x = 2.01$) on the problem solving ability test instrument. (See Table 12).

TABLE 12

Analysis of Variance Table for the Test Instrument

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig.of F
Main Effects	48.901	3	16.300	19.076	.000
Gifted	27.448	1	27.448	32.122	.000
OM Part.	14.444	1	14.444	16.903	.000
Sex	6.501	1	6.501	7.608	.006
Two-Way Interactions	.399	3	.133	.156	.926
OM Part. Gifted	.001	1	.001	.001	.972
OM Part. Sex	.395	1	.395	.462	.498
Gifted Sex	.000	1	.000	.000	.989
Three-Way Interactions	.219	1	.219	.256	.613
OM Part/Gifted/Sex	.219	1	.219	.256	.613
Residual	164.061	192	.854		
Total	213.580	199	1.073		

These findings led to the rejection of Null Hypothesis #1 since there were significant differences in problem solving achievement scores across gifted and non-gifted groups.

The second null hypothesis stated that there would be no significant difference in the problem solving achievement scores between the experimental (Odyssey of the Mind participants) and control groups (non-Odyssey of the Mind participants). The analysis of variance (ANOVA) indicated there were significant differences for the main effects across treatment groups ($F = 16.903$ $p<.01$). The students who had participated in Odyssey of the Mind (X = 2.65) scored significantly higher on the test instrument than those who had not participated (X = 2.13) . (See Table 12). These findings led to rejection of Null Hypothesis #2 since there was a significant difference in problem solving achievement scores between treatment groups.

The third null hypothesis stated that there would be no significant difference in the problem solving achievement scores across sex groups. The analysis of variance (ANOVA) indicated there were significant differences for the main effects across gender groups ($F = 7.608$ $p<.05$). The male students ($x = 2.59$) scored significantly higher than the females ($x = 2.22$) on the test instrument. (See Table 12).

It was interesting to note, however, that when statistics were computed for the OM sample only, the results were quite different. A one-way ANOVA was conducted to determine the relationships between the achievement score and gender for the OM participants. The results indicated that there were no significant differences between sex groups within the OM treatment group. These findings led to rejection of Null Hypothesis #3 since there were significant differences for the total population in problem solving achievement scores across sex groups.

<u>Results Related to Testing Null Hypothesis #4</u>

The fourth null hypothesis stated that there would be no significant difference in the problem solving achievement scores on test question #5 across the experimental (Odyssey of the Mind participants) and the control group (non-Odyssey of the Mind participants). Since the fifth question most closely resembled the type of problems on which OM participants work, it was hypothesized that more of the OM participants would solve it than the non-OM participants. The test item appeared to be the second most difficult problem on the test with only twenty two percent of the total sample correctly solving it. A crosstabs procedure revealed that of these twenty-two percent, fourteen percent were Odyssey of the Mind participants. While this percentage represented a majority of the respondents who were able to correctly answer the question, it was not significant.

In addition to the crosstabs procedure, a chi square analysis was also performed in the data set for item five. The results shown in Table 13 confirmed the previous finding that although there was some difference between the treatment groups the number was not significant.

TABLE 13

Chi Square Analysis of Test Item 5
Response by Treatment Group

	OM Participant N	Non-OM Participant N	Row Total
Correct	27	17	44
Incorrect	73	83	156
Column Total	100	100	200

Pearson Chi Square Value = 2.91375 df = 1 P = .08783

Bivariate measures of association were performed for item five as well as for every other item on the problem solving test. Phi coefficients for OM participation by test items yielded these results: phi = .21, p<.01 for item 1; phi = .14, p<.14, p<.05 for item 2; phi = .08, p = n.s. for item 3; phi = .13, p = n.s. for item 4; and phi = .12, p = n.s. for item 5. Results of this procedure confirmed that there was no significant difference in problem solving scores on test question five between the OM participants and non-OM participants. Thus, it was not possible to reject the fourth null hypothesis.

Results Related to Testing Null Hypothesis #5

The fifth null hypothesis stated that there would be no relationship between the problem solving achievement scores and years of OM experience. The results of the problem solving test instrument were analyzed to determine if students who had participated in Odyssey of the Mind for a longer amount of time scored higher than those who had been involved for a shorter time period.

Bivariate statistics for the OM participants were also computed between the total score on the test instrument and the number of years in the OM program. Results indicated that within the OM program, participants' total scores did not vary as a function of years in OM ($r = .09$). Based on these findings, Null Hypothesis #5 was not rejected because there were no significant differences found between the number of years participants were involved in Odyssey of the Mind and their problem solving achievement.

Results Related to Testing Null Hypothesis #6

The sixth null hypothesis stated that there would be no relationship between the problem solving achievement scores and success levels of OM participants.

The results of the problem solving instrument were analyzed to determine if students who had experienced more success in the Odyssey of the Mind competitions scored higher than those who hadn't competed at as high of a level. Some of the OM participants competed only in a school intramural-type contest and did not go outside their school districts. Conversely, certain OM participants won the regional and state competition levels and represented the state of Illinois in the World Finals.

Bivariate statistics for the OM participants were computed between the total score on the test instrument and the highest level of competition in which the students had competed. The findings indicated that within the OM program, participants' total scores did not vary as a result of the success levels in OM (eta = .10).

The zero-order relationships were examined and it was determined that the success levels did not appear to be significantly related to the dependent measure of total score. Based on the above results, Null Hypothesis #6 failed to be rejected because there were no significant relationships revealed between problem solving achievement and success levels in Odyssey of the Mind.

Results Related to the Teacher Rating Scale (Hypothesis #7)

A second way in which problem solving ability was measured was through the use of a rating scale previously discussed in Chapter Three. Teachers were asked to use a rating guide to rate the students on a scale from one (very good problem solving ability) to five (very poor problem solving ability) to indicate the amount of problem solving ability they thought each of their students had. The ratings were based on teacher observation and judgement as they reviewed the students' work and attitude toward problem solving within the context of their classrooms and/or schools.

In Table 14, the various means when the ratings were reviewed in respect to groups of sex, giftedness and treatment are reported. Females (x = 2.47) were given a better rating than the males (x = 2.52). The gifted students (x = 2.42) were rated better than those that were not gifted (x = 2.56) and Odyssey of the Mind participants (x = 2.39) were viewed as better problem solvers than those students who had never participated in the program (x = 2.59).

TABLE 14

Teacher Rating Means by Sex, Giftedness and Treatment

Group	N	X
Sex		
Females	109	2.47
Males	91	2.52
Giftedness		
Gifted	100	2.42
Non-Gifted	100	2.56
Treatment		
OM Participant	100	2.39
Non-OM Participant	100	2.59

Total Population X = 2.49
Rating Key:
1 = Very Good, 2 = Good, 3= Average, 4 = Poor, 5= Very Poor

The findings reported in Table 15 indicate that in all cases (as it was with the problem solving instrument), students who participated in Odyssey of the Mind received better scores than their non-participating counterparts. The gifted males who participated in Odyssey of the Mind received the best rating of all the respondents (x = 2.18). Conversely, the males who were not gifted and who did not participate in OM received the worst rating of all the respondents (x = 2.82).

TABLE 15

Teacher Rating Means by OM Participation, Sex and Giftedness

	OM Participants N	X	Non-OM Participants N	X
Male	43	2.42	48	2.60
Female	57	2.37	52	2.58
Gifted	50	2.32	50	2.52
Non-Gifted	50	2.46	50	2.66
Gifted/Male	22	2.18	26	2.42
Non-gifted/male	21	2.67	22	2.82
Gifted Female	28	2.43	24	2.63
Non-gifted/Female	29	2.31	28	2.54

Total Population X = 2.49
Rating Key:
1 = Very good, 2 = Good, 3 = Average, 4 = Poor, 5= Very Poor

The seventh null hypothesis stated that there would be no significant difference in the problem solving ratings given by teachers between the experimental (OM participants) and the control groups (non-participants). Teachers who participated in the study received a guide for rating student problem solving ability. (See Appendix A). The teachers used this guide to rate each student on a scale from one (very good problem solving ability) to five (very poor problem solving ability) to indicate the amount of problem solving ability they thought each student possessed. Teachers rated their seventh grade students who had participated in Odyssey of the

Mind and the non-OM participants enrolled in the same math classes as the OM participants.

The ratings were analyzed using a 2 x 2 x 2 factorial analysis of variance (ANOVA) to determine if participation in OM, giftedness, or gender made a difference in the rating. The analysis of variance (ANOVA) results shown in Table 16 indicate that there were no significant differences for the main effects across treatment groups nor were there any significant three-way interaction effects. However, there was a significant two-way interaction between giftedness and gender ($p<.05$). (See Figure 1).

TABLE 16

Analysis of Variance Table for Teacher Ratings

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig.of F
Main Effects	3.084	3	1.028	1.153	.329
OM Participation	1.950	1	1.950	2.186	.141
Gifted	1.010	1	1.010	1.132	.289
Sex	.104	1	.104	.116	.734
Two-Way Interactions	3.641	3	1.214	1.361	.256
OM Part. Gifted	.008	1	.008	.009	.926
OM Part. Sex	.002	1	.002	.003	.958
Gifted Sex	3.639	1	3.639	4.081	.045
Three-Way Interactions	.043	1	.043	.049	.826
OM Part Gifted Sex	.043	1	.043	.049	.826
Residual	171.212	192	.892		
Total	177.980	199	.894		

Figure 1 shows a disordinal interaction of difference in the ratings students received from their teachers. Non-gifted females (x = 2.42) were given better ratings than the gifted females (x = 2.52) and non-gifted males (2.74) received poorer scores than the non-gifted females.

Figure 1

Interaction Effects Between Teacher Ratings and Gender

Since there were no significant differences in the main effects between teacher ratings and OM participation, Null Hypothesis #7 failed to be rejected.

Results Related to the Self Rating Instrument (Hypothesis #8)

A third way in which problem solving ability was measured was through the use of a self-rating scale for the students. The respondents were asked to give themselves a score from one (a very good problem solver) to five (a very poor problem solver) to show how good of a problem solver they thought they were.

In Table 17 the various means when the ratings were reviewed in respect to groups of sex, giftedness and treatment are reported. Males (x = 2.40) gave themselves a better score than the females (x = 2.62). The gifted students (x = 2.42) rated themselves better than those that were not gifted (x = 2.62) and Odyssey of the Mind participants viewed themselves the best of all three groups (x = 2.30). The group of students who had not participated in OM rated themselves the worst of all three groups (x = 2.74).

TABLE 17

Self Rating Means by Sex, Giftedness and Treatment

Group	N	X
Sex		
Females	109	2.62
Males	91	2.40
Giftedness		
Gifted	100	2.42
Non-Gifted	100	2.62
Treatment		
OM Participant	100	2.30
Non-OM Participant	100	2.74

Total Population X = 2.52
Rating Key:
1 = Very good, 2 = Good, 3= Average, 4 = Poor, 5= Very Poor

The findings reported in Table 18 indicate that in all cases (as it was with both the problem solving instrument and the teacher ratings), students who participated in Odyssey of the Mind rated themselves better than their non-participating counterparts. The gifted males who participated in Odyssey of the Mind gave themselves the best rating of all the respondents (x = 2.14). In contrast, the females who were not gifted and who did not participate in OM viewed themselves as the poorest problem solvers of all the respondents (x = 3.07).

TABLE 18

Self Rating Means by OM Participation, Sex and Giftedness

	OM Participants N	X	Non-OM Participants N	X
Male	43	2.26	48	2.52
Female	57	2.33	52	2.94
Gifted	50	2.22	50	2.62
Non-Gifted	50	2.38	50	2.86
Gifted/Male	22	2.14	26	2.46
Non-gifted/male	21	2.38	22	2.59
Gifted Female	28	2.29	24	2.79
Non-gifted/Female	29	2.38	28	3.07

Total Population X = 2.52
Rating Key:
1 = Very good, 2 = Good, 3= Average, 4 = Poor, 5 = Very Poor

The eighth null hypothesis stated that there would be no significant difference in the self-ratings for problem solving ability between the experimental and control groups. The respondents were asked to give themselves a score of one (a very good problem solver) to five (a very poor problem solver) to show how good of a problem solver they thought they were. The ratings were analyzed using a 2 x 2 x 2 factorial analysis of variance (ANOVA) to determine if participation in OM, giftedness, or gender made a difference in the ratings students gave themselves.

The analysis of variance (ANOVA) results presented in Table 19 indicate that there were no two-way nor three-way interaction effects. However, there were significant differences for some of the main effects. Significant differences existed between the ratings of students in the two treatment groups ($F = 20.035$, $p<.01$). Students who participated in Odyssey of the Mind ($x = 2.30$) gave themselves better ratings than those who did not participate in the program ($x = 2.74$). The findings also revealed that there were significant differences between the gender groups ($F = 5.660$, $p<.05$). Males ($x = 2.40$) perceived themselves as better problem solvers than the females ($x = 2.62$).

Based on these findings Null Hypothesis #8 was rejected because there were significant differences in the self-ratings for problem solving ability between the experimental and control groups.

TABLE 19

Analysis of Variance Table for Self-Ratings

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig.of F
Main Effects	14.559	3	4.853	9.539	.000
OM Participation	10.193	1	10.193	20.035	.000
Gifted	1.761	1	1.761	3.462	.064
Sex	2.879	1	2.879	5.660	.018
Two-Way Interactions	1.400	3	.467	.917	.433
OM Part. Gifted	.030	1	.030	.059	.808
OM Part. Sex	1.347	1	1.347	2.647	.105
Gifted Sex	.000	1	.000	.000	.998
Three-Way Interactions	.280	1	.280	.550	.459
OM Part Gifted Sex	.280	1	.280	.550	.459
Residual	97.680	192	.509		
Total	113.920	199	.572		

Relationship Between Problem Solving and Rating Scale Measures

Although the rating scale measurements were much more subjective than the score from the problem solving instrument, there appeared to be a high degree of consistency between them. Table 20 illustrates that for the most part, students who were rated as the best problem solvers by themselves and their teachers scored the highest on the test instrument. The only time the directionality of the ratings were not consistent for both the teacher and the self-ratings was for the group of students rated as the worst problem solvers. For both of these ratings, the students rated as worst actually performed better on the test instrument than those rated poor. (See Table 20).

TABLE 20

Test Means by Teacher and Self-Rating Groups

Rating Group	Teacher Rating		Self-Rating	
	X	SD	X	SD
Worst	2.33	1.53	2.00	.00
Poor	2.15	1.39	1.92	.95
Average	2.26	.97	2.17	1.11
Good	2.52	.88	2.62	.88
Best	2.63	1.14	2.77	.24

An Examination of the Relationships Between the Independent Variables and Problem Solving Ability

To further examine the relationships between the dependent measure of problem solving ability and the independent variables of sex, giftedness, and OM participation, a nonparametric correlational analysis was performed.

The intercorrelation matrix and the results of the Kendall correlation coefficients and their zero order correlation tests of significance are presented in Table 21. The total score and self-ratings correlated significantly with each of the independent variables and with each other. Although statistically significant, however, the correlation coefficients were low.

TABLE 21

Intercorrelation Matrix and Kendall Tests of Significance

	Sex	Teacher Rating	Giftedness	OM Part.	Self Rating	Total
Sex		-.02	.05	-.05	.18**	.17**
Teacher Rating			.05	.10	.18**	.12*
Giftedness					.14*	.34**
OM Participation					.27**	.21**
Self Rating						.21**

* = p<.05; ** = p<.01

Further analyses were conducted through the use of a crosstabs and regression procedure to gain additional information about the relationship between the independent variables and the dependent measure of problem solving achievement. A crosstabs procedure was used to give an indication of the relationship among the variables under study. Significant relationships were found between the total score from the test instrument and the variables of school, teacher rating, giftedness, OM participation, years in OM, sex, and the scores for the individual test items. The Contingency Coefficient

(Cramer's V values) for these variables are shown in Table 22, along with their levels of significance.

TABLE 22

Significant Relationships Among Variables from Crosstabs Procedure

Total by	Cramer's V	Significance	Contingency Coefficient	Significance
School	0.22250	0.03293		
Tchr Rate			0.35143	0.03938
Gifted	0.38057	0.00001		
OM Part.	0.22937	0.03791		
Years OM			0.42065	0.00322
Sex	0.24905	0.02435		
Item 1	0.34804	0.00011		
Item 2	0.67250	0.00000		
Item 3	0.67036	0.00000		
Item 4	0.64161	0.00000		
Item 5	0.35762	0.00006		

The next task in the analysis was to identify a subset of variables best suited to predict the total problem solving score (the dependent variable). An inspection of the data led the investigator to consider a number of variables for elimination prior to performing the regression analysis. The level of success attained in OM was eliminated because it did not appear to be related to the dependent variable (total score). The information of whether participation in OM helped the participants become better problem solvers was eliminated because it had a significant relationship to only the self-ratings and the number of years in OM. Self-ratings, while showing a significant relationship in the Crosstabs procedure to OM participation, type of OM problem, better problem solver, and test items two and four, did not bear a significant relationship with the total problem solving score. It, too, was eliminated.

The type of problem on which the OM participants most liked to work was significantly related to both school and self-rating, but had no significant relationship with total score. The interrelationships among these variables seems reasonable. The strength of a school's curricular program could very well determine the type of problem worked on in OM. Further, the way a student rates him or herself might have a bearing on the student's preference for and performance on one of the problem types available (i.e., drama, structure, technology, or a combination of the three). For these reasons, the type of problem was eliminated from the regression analysis as an independent variable.

Test item five represented a redundancy in measurement. The dependent variable of total score consisted of the number of items each student correctly answered. Item one to item five, then, were eliminated from the regression, since they were totally subsumed in the total score.

<u>Regression:</u>

The remaining six variables (school, sex, teacher rating, giftedness, self-rating, and years in OM) were regressed on the total problem solving score, using a backward elimination procedure. Taken as a group, these six variables accounted for .23567 of the total variance. The F-ratio was significant at the .0000 level. School was eliminated at step 7 in the procedure. Its standardized beta weight was -.035315 (p =.5878). Teacher rating was eliminated at step 8, with a nonsignificant standardized beta weight of -.086579 (p = .1786). Self-rating was removed at step 9 (beta = -.110947, p = .1025).

The variables withstanding elimination were considered to be part of the optimal subset and consisted of years in OM, sex, and giftedness. OM participation and years in OM were highly intercorrelated, with a Cramer's V of 1.000 (if both data elements are viewed as categorical) and a Spearman's correlation of -.94105 (if the two data elements are viewed as ordinal in nature). Both the Cramer's V and Spearman's Coefficients were found to be significant at the .00000 levels. This led the researcher to believe that these indicators represented measures of the same thing. OM participation, consequently, was chosen by the researcher to represent participation in the OM program, particularly since it could be dummy coded and used in the regression to distinguish between the two groups.

The Prediction Equation:

The next step in the analysis involved identifying a prediction equation. The goal was to be able to predict the total score for both the group of students who participated in OM and the group of students who did not. It had already been determined that sex and giftedness comprised optimal predictors when they were associated with OM participation. Regression was used as the procedure of choice for determining the prediction equation.

To accomplish the regression, OM participation was dummy coded, with a "0" representing participation and a "1" representing non-participation. An interaction vector was created by multiplying the OM participation dummy code by sex and by giftedness, using the compute command of SPSSX. No other special coding was performed on sex and giftedness.

Main effects were entered into the regression first, yielding a multiple R-square value of .22896, a highly significant value ($F = 19.40$, $p < .0000$). The interactions were also found to be highly significant when they were entered next. Their multiple R-square value was .15808 with an F-ratio of 18.495 ($p < .0000$). All the variables were entered on the next equation. Their multiple R-square value of .23082 showed a high level of significance, with the F-ratio being 11.644 ($p < .0000$). Together these variables accounted for approximately 23% of the variability in the total score. A table of values resulting from the regression is presented in Table 23.

TABLE 23

Regression Values for Optimal Subset of Variables

	B	Beta	Semipartial Correlation	Significance T	Explanation
01	-0.784507	-0.379579	-0.085932	0.173900	OMPart. Dummy Coded
Sex	-0.272653	-0.131386	0.092345	0.144100	
Gifted	-0.734547	-0.355406	-0.251258	0.000100	
Int 1	0.178960	0.142005	0.042989	0.495600	OMPart. x Sex
Int 2	-0.009324	-0.007481	-0.002252	0.971500	OMPart. x Gifted
Constant	3.361927			0.000000	

An examination of the beta weights in Table 23 for all of the independent variables and interactions added to the equation revealed beta weights of approximately -.38 for participation in OM, -.13 for sex, -.36 for giftedness, .14 for interaction one, and -.01 for interaction two.

This analysis indicated that the strongest relationship among the independent and dependent variables was due to Odyssey of the Mind participation and a student's giftedness. These variables are approximately three times more heavily weighted than any other variable in the equation. It is also evident that the interaction effects contributed little to the prediction equation since the amount of variability added by their inclusion in the equation was only about .1% . Thus, it is clear that the three independent variables (as prior findings showed) were clearly related to problem solving achievement.

Chapter Summary

Analyses of variance, crosstabs procedures, chi square and regression analyses procedures were used to test the hypotheses related to differences in problem solving achievement between OM and non-OM participants, gifted and non-gifted students and gender.

The relationship between student problem solving achievement and giftedness were examined in the first hypothesis. The results indicated that students who had been identified as gifted in math scored significantly higher on the problem solving test instrument than those students who were not gifted.

The second hypothesis was designed to test the relationship between student problem solving achievement and participation in the Odyssey of the Mind program. The results indicated that students who had been involved in OM scored significantly higher on the test instrument than those students who had not participated in the program.

The relationship between problem solving achievement and gender was studied in the third hypothesis. The findings indicated that male students scored significantly higher than female students when the total population was examined. However, when the OM participants were looked at as a subgroup, the gender differences were no longer significant.

The relationship between test item five and participation in Odyssey of the Mind was examined in the fourth hypothesis. The results showed that subjects in both treatment groups (OM participants and non-OM participants) performed equally well on the fifth test item regardless of their participation in Odyssey of the Mind.

The fifth hypothesis was designed to study the relationship between problem solving achievement and the number of years of participation in Odyssey of the Mind. The findings indicated that the number of years of participation in OM appeared to have no impact on student problem solving achievement--students did as well regardless of their time in the program.

The sixth hypothesis was used to look at the relationship between problem solving achievement and Odyssey of the Mind success levels. The results indicated that the competitive success a student experienced in OM had no impact on problem solving achievement--OM participants performed equally well on the test instrument regardless of the competition level they attained.

The seventh hypothesis was designed to examine the relationship between teacher ratings of student problem solving ability and participation in Odyssey of the Mind. The results indicated that participation in OM had no impact on the way teachers perceived their students math problem solving abilities.

The eighth hypothesis was crafted to test the relationship between students' perception of their own problem solving abilities and participation in Odyssey of the Mind. The results indicated that both OM participants and males viewed themselves as better problem solvers than did the other groups of respondents.

Finally, it should be noted that these results should be interpreted with some caution, since a cross-sectional design does not always permit cumulative benefits of Odyssey of the Mind participation, mathematics instruction, or other treatments from surfacing.

CHAPTER V

DISCUSSION

In recent years, there has been a reform movement to improve the way in which mathematics is taught and to put emphasis on the teaching of problem solving skills. As a result, educators have been presented with many new programs and textbooks that attempt to integrate problem solving into the mathematics curriculum. This investigation was an attempt to provide answers to some questions regarding the possible transfer of learning from one particular creative problem solving program (OM) to the area of mathematics instruction.

Eight hypotheses were developed. The first four hypotheses were related to testing for differences in problem solving performance between a control group and an experimental group (Odyssey of the Mind participants). Results were also tested for differences between students who had been identified as gifted and their non-gifted counterparts and between genders. The fifth and sixth hypotheses were related to differences in mathematical achievement among Odyssey of the Mind participants. Problem solving scores were studied to determine if the number of years of participation in OM or the level of success attained by the participants affected problem solving achievement. The seventh and eighth hypotheses were related to differences in perceived mathematical problem solving ability between a control group and an experimental group that consisted of Odyssey of the Mind participants. Teacher ratings and self-ratings were used to determine if differences existed in the perceived problem solving abilities among OM participants and non-OM participants; gifted and non-gifted students; and males and females.

The sample consisted of 200 seventh grade students who were randomly selected from seven public schools. The schools were located in one rural and six suburban areas of Illinois. The students were given a five-item test that was used to measure their problem solving achievement. The problems were taken from released items used in NAEP's 1986 assessment, Arithmetic Teacher, and from a study on creativity conducted by Duncker in 1945.

In addition to the problem solving test instrument, data was also collected about student ability through the use of teacher and student rating scales. Students were given a score from one to five to show how good of a problem solver they were believed to be.

The data from the sample was analyzed through the use of a combination of analysis of variance, crosstabulation procedures, chi square, and regression analyses procedures. The results from these analyses are summarized and discussed in what follows.

Discussion Related to Testing Null Hypothesis #1

Students who were identified as gifted scored significantly higher on the problem solving test instrument than those students who were not gifted. This finding was not surprising as gifted children frequently outscore their peers on tests which are academic in nature. The use of achievement test scores was, in fact, how many of the students were identified as being gifted in the first place.

However, on the other hand, many gifted programs concentrate on accelerating students through a curriculum which is based on computational skills rather than on thought-provoking problems. Instructional emphasis is placed on getting answers quickly and not on the process. In this light then, it is revealing that the gifted students outperformed the non-gifted children on a test that included non-routine problems. Perhaps this indicates that the students in this study come from gifted math programs where emphasis is placed on teaching problem solving skills and students are given time to think.

Discussion Related to Testing Null Hypothesis #2

Students who participated in the Odyssey of the Mind Program scored significantly higher on the test instrument than those students who had not participated. This finding can be interpreted in several ways. First, it could mean that transfer of learning took place between the skills learned in Odyssey of the Mind and mathematical problem solving. While the OM program does not deal specifically with mathematics, applied math is necessary to solve many of the long-term problems. This type of general practice in context-free forms facilitates transfer according to Nickerson (1985).

Secondly, students who participate in Odyssey of the Mind usually get a lot of practical math experience especially in areas like measurement since they build their own props and scenery. This additional time and experience using measurement skills most likely helped the OM participants solve test item three which involved finding the correct length of a line.

Finally, students who participate in Odyssey of the Mind learn how to persevere until they find a solution to a problem. Sometimes, this persistence lasts several months as the students solve their annual long-term problem. It is probable that this skill helped them on the test instrument especially on the tasks that required them to generate more than one answer. OM participants have also practiced taking their time to ensure that they have the best possible solution to a problem.

Discussion Related to Testing Null Hypothesis #3

There were significant differences found in the problem solving achievement scores across sex groups with male students scoring significantly higher than the females on the test instrument. This result supports much of the research that has taken place during the last fifteen years. Different explanations have been offered to account for the gender differences in mathematics. Some of the more common explanations include such variables as ability, confidence, motivation, sex-role congruency, teacher expectations and beliefs, teacher interactions toward each sex, difference in leisure-time activities, and student attitudes toward math.

One of the first persons to address the issue of gender differences in mathematics achievement in a book was Sheila Tobias in her 1978 manual, Overcoming Math Anxiety. In her book, Tobias described a survey conducted by John Ernest, a professor at the University of California in 1974. Ernest's survey indicated that **both** boys and girls in junior and senior high school had some degree of difficulty with math and most of them did not like the subject. The difference between them was that boys stayed with math because they believed their careers depended on it and because they had more confidence than girls in their ability to learn it.

Tobias reported that the gap in math abilities (especially problem solving) began at about age 13 and got greater as students got older. She attributed this gap to the differing amounts of societal pressure placed on boys and girls to excel in math. Girls received less societal pressure than boys. The difference in pressure created increasingly larger gaps in ability as math got harder and required more work and committment throughout the upper grades.

Recently, Elizabeth Fennema and Gilah Leder (1990) authored a book, Mathematics and Gender, which was devoted entirely to the subject of gender differences in math achievement. Fennema stated that gender differences definitely exist in mathematical achievement but that it has declined in recent years.

It was encouraging to find that within the Odyssey of the Mind treatment group there were no significant differences found between the genders. The results suggest that OM may perhaps "level" the gender differences of boys being better math problem solvers than girls.

The importance of this finding was highlighted in a recent study commissioned by the American Association of University Women, a group which is dedicated to improving educational opportunity for females. In discussing the study, Anne Bryant, the executive director of the association (in Mohnke 1991), said that although there has been a lot of talk about reforming and restructuring of the educational system, there has been little said about the changes which must be made in order for schools to do a better job of educating girls. Bryant went on to say that the country could not afford to suffer the loss of talent that occurs when girls are inhibited from achieving their full potential.

The fact, then, that participation in Odyssey of the Mind allowed girls to achieve at least at the same level as boys is very significant indeed and seems to be the exact type of educational change that Bryant says is not addressed by the current reform movements. OM might be one of the few existing programs that has a positive effect on all of the students that are involved in it regardless of their sex.

Since gender differences existed in the total population of the study, the variables of student confidence and teacher beliefs will be looked at later on in this chapter. These variables will be examined to see what kind of effect they might have had on problem solving achievement. They will also be studied to see how they might explain the gender differences in this study.

In addition to examining the scores from the problem solving test instrument, the investigator also looked at student and teacher perceptions of the problem solving ability they believed each of the respondents to possess. The following section looks at the findings as they related to the results from the rating instrument.

Discussion Related to Testing Null Hypothesis #4

No significant difference was found on item five between the respondents in the two treatment groups. Test item five consisted of a creative problem solving task that asked the students to attach a candle to a wall using matches and tacks to help them if desired. Most of the respondents tried to attach the candle by sticking tacks through the candle. Only twenty-two percent of the students thought creatively and emptied out the box of matches or tacks in order to use the box as a holder for the candle. This type of thinking required the students to think of a different use for a common object.

The lack of significant difference between the treatment groups might best be explained by the fact that the task was too difficult for the total sample. As Duncker discovered in his studies of 1945, subjects had a difficult time solving this problem effectively because they were "fixated" on the use of the box as a container for the fasteners and therefore were not able to conceive of the box as a platform for the candle.

Although the majority of the twenty-two percent who correctly solved the problem were OM participants (14%), the difference between the groups was not found to be significant.

Discussion Related to Testing Null Hypothesis #5

No significant difference was found for the problem solving scores between students who had participated in Odyssey of the Mind for a longer amount of time and those OM participants who had been involved for a shorter period of time. These findings indicate that there is no relationship for students in the Odyssey of the Mind Program, between amount of time spent in the program and performance on the problem solving test instrument. However, it is perhaps best to assume that the relationship be considered inconclusive at this time since the distribution of years in OM was highly skewed with almost sixty percent of the OM participants in the study being in OM for only one year. More students who spent a longer time in the program would be needed in order to report a more conclusive finding.

Discussion Related to Testing Null Hypothesis #6

There was no significant difference found for the problem solving scores between the OM students who had experienced more competitive success and those OM students who did not advance to as many competitive levels. This finding indicates that while participation in the Odyssey of the Mind program can predict student problem solving achievement scores, the higher scores do not seem to be related to how successful an OM team is in competition. Attending team meetings, practicing spontaneous and long-term problem solving skills and performing in front of at least one judging audience can be powerful enough to predict problem solving scores.

Discussion Related to Testing Null Hypothesis #7

There was no significant difference found between the ratings teachers gave the Odyssey of the Mind participants and those given to the non-participants. However, there was a significant interaction effect between the gifted and gender groups. Non-gifted females were given higher ratings than both the gifted female and non-gifted male groups. Although there was a significant interaction effect, it is difficult to meaningfully account for it. This finding may be due to confounding chance factor possibly as a result of having used a subjective rating scale and having had different teachers assign each student their rating.

The area of teacher beliefs is one that researchers began studying more after Rosenthal and Jacobson's study, Pygmalion in the Classroom, was published in 1968. Good and Brophy (1987) reviewed research studies and suggested that teacher expectation effects caused students to achieve more or less than they would have achieved otherwise. Since there was no significant difference in the way teachers viewed the problem solving ability of OM participants and non-participants, it would suggest that the higher scores on the test instrument were caused by higher ability and not from a self-fulfilling prophecy effect. Thus, the OM participants scored significantly higher on the test instrument than the non-OM participants regardless of what their teachers believed their ability to be.

Discussion Related to Testing Null Hypothesis #8

There were significant differences found in the way students viewed their problem solving abilities between Odyssey of the Mind participants and non-OM participants and between genders. OM participants reported themselves to be better problem solvers than the non-OM participants and males reported themselves to be better problem solvers than the females. The gender differences were consistent with the findings from the Fennema and Sherman studies conducted in 1977 and 1978 (in Fennema, 1990). They found that males in grades six through twelve consistently showed greater confidence than females in their ability to learn mathematics. They also found that initially these differences were not reflected in differences in achievement. However, for the older students, they reported that confidence in math was a good predictor of performance for females but not for males.

Fennema reported that confidence was more strongly correlated with achievement than was any other affective variable measured in their study.

The difference in the confidence between the OM and non-OM participants suggest that the experience with Odyssey of the Mind helped students to become more comfortable with problem solving. Students are trained in OM to work with a long-term problem until it is solved. Student confidence is built up when students realize that they can solve tough problems.

The non-OM participants were likely to have the type of experience many students have in math classes. Students attempt to solve a problem and are given the answer in class the next day even if they have not been able to work on the problem. Thus, they might not have had as much opportunity to build up confidence in their problem solving ability.

Confidence influences a student's willingness to approach new material and to persist when the material becomes difficult. It is not surprising to find that OM participants had more confidence in their problem solving ability since Odyssey of the Mind continuously confronts students with new material and problems to solve.

Effects of Odyssey of the Mind on Problem Solving Achievement

With respect to mathematical problem solving achievement, the findings reported here indicated statistically significant differences between Odyssey of the Mind participants and non-OM participants; gifted and non-gifted students and males and females.

The Odyssey of the Mind participants scored significantly higher than the non-OM participants on the test instrument. The gifted students outperformed the non-gifted students. Males scored higher than females on the test instrument when the population was looked at as a whole. However, when statistical tests were conducted on the OM sample, there was no difference in problem solving achievement between male and female Odyssey of the Mind participants.

Among the OM participants, there were no significant differences found in problem solving achievement for the number of years in Odyssey of the Mind or for the level of success attained in competition. Thus, although the Odyssey of the Mind program was a good predictor of problem solving performance, the predictability did not seem to vary with how long a child had participated in the program or how many months a year he/she practiced in preparation for competitions.

There were also no significant differences found for teacher ratings of the student problem solving abilities between OM participants and non-OM participants, gifted and non-gifted students or males and females. However, OM participants received higher ratings than non-OM participants, gifted students were given higher scores than the non-gifted and males were rated higher than the females in the study.

On the self-ratings, analysis of the findings indicated statistically significant differences between Odyssey of the Mind participants and non-OM participants and males and females. The OM participants viewed themselves as better problem solvers than the non-OM participants and males scored themselves higher than the females.

There were no statistically significant differences found for self-ratings between the gifted and non-gifted students. Nevertheless, the gifted students rated themselves as better problem solvers than the non-gifted students. Throughout these results, students who had participated in the Odyssey of the Mind program performed significantly well. These results should be interpreted with some caution, since a cross-sectional design does not always permit cumulative benefits of Odyssey of the Mind participation, mathematics instruction, or other treatments from surfacing.

Generalizability of Findings

Upon reviewing the findings, careful consideration must be given to the limitations inherent in this study. The main delimitation stems from the fact that the treatment (Odyssey of the Mind) had already been given. Since students had already participated in the program prior to this study, the use of a pre-test became meaningless. It would have been informative to have known the ability level at which the students were working before ever having participated in Odyssey of the Mind.

Another limitation that arose because of the treatment already having taken place was that there was no standardized way of providing treatment in each of the schools. There would most likely have been variations in the amount of time and manner in which skills such as divergent thinking, measurement, set construction, problem solving, etc. were taught.

An additional limitation of the study is the way in which the test instruments were administered. The tests were not administered by the same person in all of the schools. Although a script was provided to the teachers who gave the tests, there might still have been variations in the way they were given.

Further research must be conducted in order to determine whether or not the above listed limitations affected the generalizability of the findings. Nevertheless, there are several implications which can be made based on the available results.

Implications for Practitioners

The major objective of this investigation was to create an empirical data base which practitioners could draw upon when designing instructional programs that would integrate problem solving into the curriculum. As Jagielski (1990) reported, research studies and reports have indicated how important problem solving is as one of the basic skills of mathematics. However, the studies and reports have failed to indicate how to effectively integrate problem solving into the mathematics curriculum.

Based on the findings of this study, it is clear that the Odyssey of the Mind program has many benefits outside of its competitive arena. The results suggest that transfer of learning took place between Odyssey of the Mind and the area of mathematics. Students who participated in OM not only believed themselves to be better problem solvers but were better problem solvers than those students who did not participate in the program.

Overall, the findings suggest that the Odyssey of the Mind Program can be a powerful predictor of problem solving achievement. Statistically significant results were found in this study even though almost 60% of the OM population had participated in the program for only one year. Quite a profitable return for only a one-year investment.

As we invest in our children's futures and begin to prepare them for tomorrow's work force, it is time to bring our educational system into the 21st century. Programs like Odyssey of the Mind should be incorporated into the daily school curriculum. Hands-on problem solving experiences, creative thinking and teamwork should be taught in all classes especially math. The students might reap many more benefits from math instruction of this type than they would have from being taught rote memorization of facts. Girls, in particular, would seem to benefit the most from Odyssey of the Mind since it appeared to help them become as capable at problem solving as the boys. Girls begin elementary school leading the boys in math and science. But, the girls soon begin to fall behind in these subjects and the achievement gap grows throughout their school years. OM might be one of the few programs that can do something about correcting this continuing problem. Once this type of curriculum is implemented where all students benefit perhaps the United States will begin scoring above the international averages in future studies.

Recommendations for Further Research

While the study reported here provided information on the effects Odyssey of the Mind can have on problem solving achievement, there are areas which require further investigation. Longitudinal studies which begin before students become involved in OM and continue until after students have stopped working in OM need to be conducted. This would provide information as to the cumulative benefits of participation in Odyssey of the Mind. The investigation should also be expanded to include students in more than one grade level to see if age or grade makes a difference.

This study should be replicated with a pre-test given before the Odyssey of the Mind treatment has taken place. Both affective and cognitive items should be included on the test. Following a year or more time, a post test should be administered to both the control and experimental groups. Using the pre-test as a covariant, results should be analyzed to determine if there are significant differences between the groups in either achievement levels or personality types.

The problem solving test instrument used to collect data should be revised in future studies. Perhaps more than five items should be used in order to gain additional information from the results of different types of problems. Easier problems should also be used so that a higher success rate is achieved by students.

More research is needed to investigate the OM training environments in each of the schools that participated in the study. Since there wasn't a standard way of working with the Odyssey of the Mind program across the schools, studies will have to be done to determine if there are particularly effective ways of training students in the type of creative problem solving used during Odyssey of the Mind.

Additional research should be conducted on different problem solving programs. Although OM was used in this study, there are other competitions such as Future Problem Solving Bowl and Invent America that warrant investigation. It would be interesting to compare student achievement between each of the different programs.

Finally, a study should be done to determine if the transfer of learning effects would be changed if the OM training took place as part of the required daily curriculum rather than as an extracurricular activity.

The results of this study and any others that result from the current one may be what's needed to begin changing the curriculum of the 20th century so that the educational system will start meeting the challenges that face us ahead in the 21st century.

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APPENDIX A

Please return the completed form to Terri Carman,
by October 1, 1990.

Teacher Interest Survey

Name_______________________________________

School_______________________________________

Work Phone and best time to reach you_______________________

Home Phone and best time to reach you_______________________

☐ I am interested in participating in the problem solving study if selected (Go on to question one).

☐ I am not interested in participating in the problem solving study (Return this form in the envelope provided). Reason:

1. In my school, OM is offered to:

☐ any student that is interested

☐ only students in the gifted program

2. How many seventh graders do you have in your school?

3. How many seventh grade math classes do you have during the day at your school?

4. Approximately how many seventh graders have participated in OM anytime during the past?

5. Approximately how many of these participants have been identified as gifted in math? State the criteria your school uses for identification.

6. OM is taught:

☐ during the school day (specify the class in which it is taught)

☐ as an extra-curricular activity

7. Teams are coached by:

☐ teachers

☐ parents

☐ other (please specify)

8. Team meetings/practices are held at:

☐ school

☐ a parent's home

☐ other (please specify)

9. Approximately how many hours a week does an average team from your school practice?

Additional comments (You can use the back side of paper for more space):

Student Problem Solving Ability Rating Guide

Teachers:

Please rate each child's problem solving ability by giving them a number from 1 to 5. The following descriptions should help to give you a more objective basis with which to judge the students. The descriptions are meant to serve only as a general guide.

1 Very good problem solving ability - the student almost always selects appropriate solution strategies*, almost always implements the strategies with accuracy, almost always tries a different solution strategy when stuck (without being helped by the teacher), almost always approaches problems in a systematic manner (clarifies the question, identifies needed data, plans, solves, and checks), shows a willingness to try problems, demonstrates self-confidence, and perseveres in problem solving attempts.

2 Good problem solving ability - the student usually selects appropriate solution strategies*, usually implements the strategies with accuracy, usually tries a different solution strategy when stuck (without being helped by the teacher), usually approaches problems in a systematic manner (clarifies the question, identifies needed data, plans, solves, and checks), shows a willingness to try problems, demonstrates self-confidence, and perseveres in problem solving attempts.

3 Average problem solving ability - the student sometimes shows a willingness to try problems depending on the nature and difficulty of the problem, sometimes approaches the problem in a systematic manner depending on the difficulty of the problem, sometimes demonstrates self-confidence in problem solving ability, sometimes uses an appropriate solution strategy*, sometimes gets incorrect answers, but the work frequently shows understanding of the problem situation.

4 Poor problem solving ability - the student occasionally shows a willingness to try problems, usually lacks self-confidence in problem solving ability, has trouble approaching a problem in a systematic manner, sometimes attempts to choose solution strategies* when solving problems but chooses inappropriately and/or can't carry out the strategies that are chosen.

5 Very poor problem solving ability - the student almost never shows a willingness to try problems, lacks self-confidence in problem solving ability, can't approach a problem in a systematic manner, doesn't persevere in problem solving attempts, frequently gives incorrect answers, almost never shows his/her work and almost never demonstrates evidence of using a solution strategy*.

*Some possible solution strategies that students use:
1. Guess and check 2. Estimation 3. Draw a picture
4. Create a table 5. Solve a simpler problem 6. Look for patterns

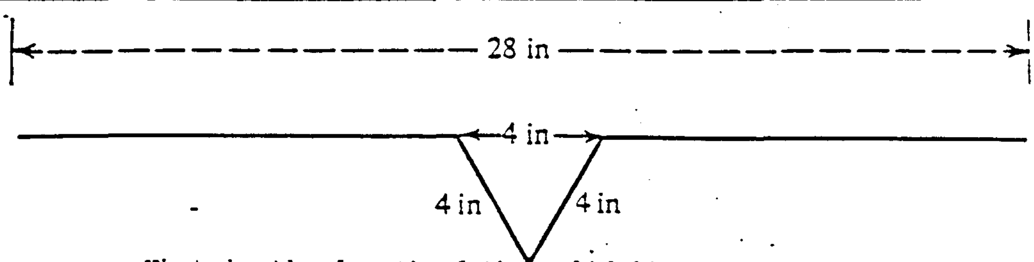
1) Dawn has 3 skirts and 5 blouses. How many different skirt-blouse outfits can she make with these?

- 3
- 5
- 8
- 15

2) Suppose you have 10 coins and have at least one each of a quarter, a dime, a nickel, and a penny. What is the least amount of money you could have?

- 41¢
- 47¢
- 50¢
- 82¢

3)

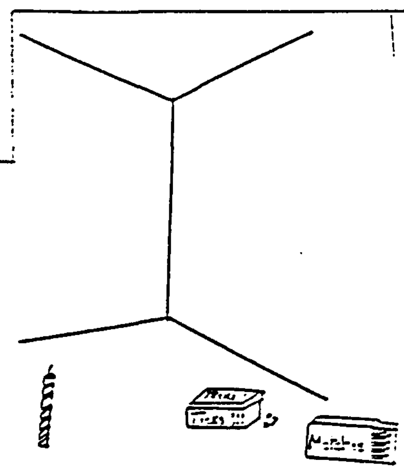


What is the length of the solid line?

ANSWER________inches

4) House numbers can be made with the numbers 0, 1, 2, 3, 4, 5, 6, 7, 8, or 9. My house number has three different digits. The sum of the three digits is 6. The number does not begin with 0. What could my house number be? List all the possible numbers.

5) Explain and/or draw how you would attach a candle vertically to a wall to serve as a light. You may use the available materials (a box of tacks and a box of matches) to help you.



APPROVAL SHEET

The dissertation submitted by Terri Spreckman Carman has been read and approved by the following committee:

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The final copies have been examined by the director of the dissertation and the signature which appears below verifies the fact that any necessary changes have been incorporated and that the dissertation is now given final approval by the Committee with reference to content and form.

The dissertation is therefore accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

September 30, 1991
Date

Diane Schiller
Director's Signature