The Characteristics of Problem Solving Transfer in a Montessori Classroom

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ABSTRACT

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Montessori Classroom

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The purpose of this case study was to examine the use of problem solving strategies and instruction within the Montessori model of learning and to determine if problem solving and transfer occurred. The following research questions were investigated:

1. What Montessori model characteristics are similar to the characteristics reported in the problem solving research which facilitate transfer?
2. In what ways does problem solving within the Montessori classroom transfer?
3. What are the factors that influence problem solving transfer in a Montessori classroom?

The site for the study was a fourth through sixth grade level classroom in a private, non-profit Montessori school. Participating in the research were 16 students, two teachers, and a parent of each of the students. The study was conducted over an eight month time period.

Data collection and analysis involved both qualitative and quantitative methods. The qualitative data were gathered through video-taping of 24 classroom lessons, audio-taping interviews with the students, teachers, and parents and curriculum document analysis. Quantitative instruments included the TONI-3: Test of Nonverbal Intelligence, 3rd Edition, the Problem Solving and Thinking Processes scale, the Flanders Interaction Analysis Categories-Modified, and the Engagement Check.

These are the findings: (a) as implemented in this study, the Montessori model of learning did incorporate instructional strategies that facilitated problem solving and transfer; (b) instances of problem solving, problem solving transfer, and knowledge transfer did occur; and (c) six specific instructional and curriculum strategies influenced the opportunities for problem solving and transfer in the classroom. This research contributes to the field by studying transfer with elementary age students in the natural setting of a classroom and by providing a framework for examining the factors which encourage problem solving.

The Characteristics of Problem Solving Transfer in a Montessori Classroom

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CHAPTER ONE

The Changing Workplace

Today's competitive environment is experiencing significant and rapid changes in technology, worldwide expansion, population shifts, and consumer expectations. Businesses must possess the capability to respond quickly and effectively to a changing marketplace and to maintain a competitive edge. An organization's internal structure and employees must be able to change with the external environment (Blanchard & Thacker, 1999). Motorola University's Director of Strategic Information stated that the success of many businesses will depend on their ability to adapt to constant change (Filipczak, 1994).

In changing environments, organizations must find nontraditional and empowering ways of organizing and managing people. Workers' sense of responsibility and creativity become paramount to the success of an organization (Clawson, 1999). Simply providing work-related knowledge and skills to employees is not enough to effectively compete in the workplace of the future (Blanchard & Thacker, 1999).

The composition of the workplace is changing, and the need for more highly skilled workers is growing. Berryman described "higher skill occupations" as those in which the required education levels surpass the average amount of education for the workforce as a whole. Statistics from the U.S. Bureau of the Census and the Bureau of Labor Statistics indicate a steady increase between 1900 and 1990 in the proportion of the work force in occupations requiring higher level skills. Since 1975, the demand for higher skilled workers has grown at approximately 2.5 times the rate for lower skilled workers. Projections from the Bureau of Labor Statistics show a continued demand into the next century (Berryman, 1993). This need for adaptive work environments and more highly skilled workers is determining the type of organizational structure seen in the workplace.

Bureaucratic vs. Organic Work Structures

Historically, work was repetitive, stable and programmed. The majority of the work in the U.S. occurred in factories, where lower skilled jobs were in demand. Workers were in positions with narrowly defined tasks, and the need for the transfer of knowledge was limited. According to Mintzberg (1993), these characteristics are typical of a bureaucratic structure, one that is standardized and predictable.

Today, the world of work is different. Companies in the U.S. are shifting from very specialized and repetitive jobs to positions requiring adaptive and cooperative teams with wide ranged responsibilities (Berryman, 1993). As the needs of the workforce have changed, the need for transferring knowledge has become increasingly (Stasz, McArthur, Lewis, & Ramsey, 1990). Modern organizations resemble the informal, organic structure which is defined by the absence of standardization (Clawson, 1999).

Bureaucratic and organic structures are considered to be at two ends of the continuum of organizational design (Mintzberg, 1993). In the age of technology the need for vertical hierarchies, inherent in bureaucracies, is disappearing. In organic structures, the employees who are closer to the work and customer often make better decisions than those who are higher in the organization (Clawson, 1999).

Problem solving skills are needed within the organic structure. Effective leaders realize an organization will not remain competitive unless people are learning and expanding their skills. "In a turbulent environment, it has become maxim that the ability to learn is the only source of sustainable competitive advantage" (Clawson, 1999, p. 145).

With the increasingly competitive workplace and the need for an adaptive workforce, it is evident that the role of education in preparing the workforce of tomorrow is critical. In the past, elementary and secondary educational practices have been relatively consistent with the way work was organized in factories, particularly for workers in lower skilled jobs (Berryman, 1993). Often schools have focused on turning out a "product" with the primary goal of teaching basic skills and content knowledge. The United States government has recognized the need for change in how tomorrow's workforce will be educated. The following provides a brief description of recent federal mandates.

Skills in the Workplace

National Education Goal Five stated that by the year 2000, "Every adult American will be literate and will possess the knowledge and skills necessary to compete in a global economy and exercise rights and responsibilities of citizenship" (National Education Goals Panel, 1990). In June 1991, the U.S. Department of Labor issued the Secretary's Commission on Achieving Necessary Skills Report (SCANS) detailing the necessary foundations and competencies required for 21st century workers. SCANS determined the foundations to be in three areas: basic skills, thinking skills, and personal qualities. Workers use these foundation skills to develop competencies in the workplace. The descriptors for each of the three areas were:

1. Basic Skills --reading, writing, speaking, listening, and arithmetic/mathematics;
2. Thinking Skills -- problem solving, reasoning, decision-making, creative thinking, seeing things in the mind's eye, and knowing how to learn;
3. Personal Qualities -- responsibility, self-esteem, sociability, self-management, integrity and honesty (U. S. Department of Labor, 1991).

At the time the report was issued, the SCANS chair, William Brock, stated that the end product ". . . must include the publication of necessary functional and enabling skills which society must provide to every child in this country by the age of 16" (Whetzel, 1992). The report was a call for education to remedy the discrepancy between skills taught in traditional learning environments and skills needed in changing workplaces. Educators were encouraged to do more than just educate students about reading, writing and arithmetic.

Recently the U. S. Department of Education released the Third International Mathematics and Science Study (TIMSS). The findings reported that many teachers in the U.S. focus on only teaching students procedures for solving math problems. Little time is spent developing connections between mathematical concepts and ideas. The findings urged educators to teach students problem solving and critical thinking skills, how to apply knowledge, and how to integrate newly acquired knowledge with prior knowledge (Dunson, 2000).

Another national report which recently examined education is *Before It's Too Late: A Report to the Nation from the National Commission on Mathematics and Science Teaching for the 21st Century*. In the Forward to the report John Glenn, the Commission chair, concluded ". . . it is abundantly clear from the evidence already at hand that we are not doing the job that we should do--or can do--in teaching our children to understand and use ideas from these fields" (Glenn, 2000, Forward). According to the report, the teaching methods in mathematics and the sciences have changed little over the past 50 years.

A Department of Education study of 81 videotaped classrooms revealed that mathematics and science teachers continue to teach by reviewing, illustrating the problem solution, drilling the students on the procedures, supervising seatwork, checking the seatwork, and assigning homework. In contrast, Japanese students are presented with problems which contain principles the students have not yet learned. Working alone or in cooperative groups, the students find appropriate solutions. Then the whole class works the problems and finds solutions together, identifying the math concepts and reasoning as they solve the problems (U. S. Department of Education, 2000).

In the Commission study, current instructional strategies in the sciences did not get a better grade than in mathematics. According to the findings, most science students spent time learning definitions or labels related to the field of study. Seldom were students taught the big concepts that make the learning of science meaningful. The report stated that students are "being crippled by content" and getting limited instruction about the science of inquiry (U. S. Department of Education, 2000, p. 17).

The educational system must better prepare individuals for the modern workplace, a workplace that requires workers to engage in activities which demand knowledge and skills acquired in other situations (Berryman, 1993). All students need to know how to think. Students need to know how to transfer knowledge and skills learned in one setting and successfully apply them in a broad array of situations (Van Tassel-Baska et al. 1988). The next section will address the topic of transfer of knowledge and the implications for learning.

Transfer from Education to the Workplace

With the explosion of information within the world, schools can not teach students everything they need to know. Students must be equipped with the ability to transfer what they have previously learned to solve new problems and to understand new information quickly (Mayer & Wittrock, 1996; Prawat, 1989).

> One of the major aims of education . . . is to increase students' ability to competently interact with a varied and changing world. To meet this goal, the student must be able to appropriately transfer knowledge and skills acquired in one setting to another (Brooks & Dansereau, 1987, p. 121).

The goal of education must be to improve the transfer of critical thinking skills from the classroom to real world problems. These skills need to be useful in the workplace and long lasting (Halpern, 1996).

Characteristics of Transfer

Within the research literature, a variety of definitions describe characteristics of transfer. For example (a) transfer takes place when our existing knowledge, abilities, and skills influence the learning of new tasks (Cormier & Hagman, 1987), and (b) transfer "occurs when a person's prior experience and knowledge affect learning or problem solving in a new situation" (Mayer & Wittrock, 1996, p. 48). The key characteristic found in both of these definitions is the focus on how prior knowledge affects the acquisition of *new* knowledge. The emphasis on *new* knowledge distinguishes transfer from mere learning.

More specifically, Mayer and Wittrock (1996) described *knowledge* transfer occurring when prior learning (task A) affects new learning (task B). Transfer of learning can be positive; that is when later acquisition or performance is facilitated, or it can be negative when future acquisition or performance is impeded. And, transfer can be specific (content dependent), or it can be general (content independent) influencing a wide range of new competencies (Cormier & Hagman, 1987).

There has been a long-standing debate on how to improve the ability to think (Block, 1985; Bruer, 1993; Halpern, 1998; Halpern & Nummedal, 1995). Given the influence of prior learning in the acquisition of new knowledge, there continues to be strong interest in understanding how to improve transfer (Cormier & Hagman, 1987).

Although many tasks in educational settings require knowledge transfer, cognitive psychologists Mayer and Wittrock (1996) distinguished between general *knowledge* transfer and specific *problem solving* transfer. They described problem solving transfer, "When a problem solver uses a previous experience with one kind of a problem to help solve a different kind of problem" (p. 48). Since teaching students how to solve problems they have not previously encountered is a primary goal of education, understanding problem-solving transfer is of critical importance to educators.

Previous research has indicated that successful problem-solving transfer does occur but not as often as one would think. Studies conducted primarily in laboratory situations (Gick & Holyoak, 1980, 1983; Reed, 1987; Reed, Ernst, & Banerji, 1974) and in other controlled settings (Lave, 1988; Rogoff & Lave, 1984; Schliemann & Acoily, 1989) indicated varied success in problem solving transfer. Research on problem solving transfer has been conducted with children (Brown & Kane, 1988; Brown, Kane & Long, 1989; Pezdek & Miceli, 1982) but seldom in naturalistic settings like classroom environments (Campione, Shapiro & Brown, 1995).

Teaching for Transfer

Berryman (1993) described the traditional view of the learner as the "passive receiver of wisdom" and how this approach to educating the workforce fit when the majority of organizations needed lower skilled employees. There was little need for workers to transfer knowledge, for the work was routine and familiar. However, a rapidly changing workplace needs employees who possess the skills to adapt to unfamiliar, non-routine events and to transfer problem solving from one situation to another. Singley and Anderson (1989) emphasized this need by stating, ". . . the problem of transfer is perhaps the fundamental education question" (p. 1). However, educators have recognized that teachers often lack the skills necessary to teach students how to think critically and solve problems. Almost 20 years ago, Goodlad (1984) wrote:

> The emphasis on facts and recall of facts in quizzes demonstrates not just difficulty of teaching and testing for more fundamental understanding

> but the probability, supported our data, that most teachers simply do not know how to teach for higher levels of thinking (p. 237).

The next section will discuss programs that have been designed for the purpose of teaching problem solving.

Programs That Teach Problem Solving

In recent years, a number of programs and courses have been developed to directly teach transferable problem solving skills. Mayer and Wittrock (1996) describe two such programs: (a) the Productive Thinking Program (Covington, Crutchfield & Davies, 1966), a course for elementary school children, and (b) Feuerstein's (1980) Instrumental Enrichment Program which requires a lengthy, time-intensive amount of instruction to implement. The authors conclude that both programs report success with problem solving transfer for similar problems but report limited results with dissimilar problems. Talents Unlimited (Schlichter, 1986), a widely used thinking skills program, proposes to enhance academic achievement and integrate thinking processes across subjects. The program addresses the need for transfer across dissimilar problems, often referred to as "far transfer." However, extensive training is necessary to implement the program (Ellis & Fouts, 1997).

After reviewing a number of the current thinking skills programs, Ellis and Fouts (1997) took a rather guarded view regarding their effectiveness. They stated:

> Thinking skills has become one of the very lucrative in-service and materials areas, and at worst preys on the vulnerability of professionals of good will who so much would like to improve the quality of students' thinking (p. 105).

In summary, the teaching of problem solving skills should be a critical component of an educational curriculum. However, many teachers do not have the knowledge to teach higher level thinking and problem solving skills to their students. Commercially produced curricula have produced mixed results with a large investment of time and money required to implement them. Therefore, specific models of education should be examined to determine if the necessary skills and approaches are inherent within the model to enhance thinking and problem solving skills for transfer. Montessori is a model of education which provides a student-centered environment that encourages independent thinking (Crain, 2000) and problem solving (Coe, 1991).

The Montessori Model of Education

The Montessori model of education is a philosophy of child development and a methodology for facilitating learning. Turner (1992) suggested that Dr. Maria Montessori's writings provide the most comprehensive description of an educational model ever produced by one individual.

Dr. Montessori's contributions to modern education may have, at times, been overlooked. For example, "Although Montessori is well known as a teacher, she is underestimated as an innovative theoretician. She anticipated much that is current in developmental thinking" (Crain, 2000, p. 84). Only within the last twenty-five years have educators begun to make the connections between the Montessori approach and what research says about the optimal ways children learn (Coe, 1991; McNichols, 1996; Montessori, 1967). Today there are Montessori programs in over fifty countries on six continents (Fero, 1997). In the United States, Montessori programs are located in all states with a total of approximately 6,000 schools (T. Seldin, personal communication, March 5, 2002).

In recent years, the number of programs greatly increased, particularly at the elementary level (T. Seldin, personal communication, March 5, 2002). However, there has been very limited reporting of research on the Montessori approach. Furthermore, the most recent studies examining learning in elementary Montessori classrooms have used achievement test results as a measure of teaching and learning effectiveness (Cisneros, 1994; Duax, 1995; Fero, 1997; Moore, 1991). To date, no studies have been conducted in elementary Montessori classrooms to examine the effectiveness of teaching problem solving. Since the Montessori model of education emphasizes problem solving (Buermann, 1992; Coe, 1991), and there are thousands of Montessori schools in the U.S. (T. Seldin, personal communication, March 5, 2002), this type of education is an appropriate model to examine.

The Purpose of This Study

The purpose of this study was to examine the use of problem solving strategies and instruction within the Montessori model of instruction, and it is an important study for several reasons. There is a need for continued study and research in the area of problem solving transfer, particularly in applied settings such as classrooms. Secondly, although the Montessori model of education stresses the importance of teaching problem solving, no studies have examined the effectiveness of this strategy within Montessori classrooms. The third supportive reason for study is the growing need to better understand how to prepare students to be successful problem solvers in the workplace of the future.

"We should be teaching students how to think; instead we are primarily teaching them what to think" (Lockhead, 1979, p. 1). Brooks and Danereau (1987) argued that many of our educational environments specify exactly what must be learned, with an emphasis on content rather than on the importance of developing relationships between previously stored information and new information. The importance of, and need for, teaching problem solving transfer in the workforce is evident.

The current study addressed these questions:

1. What Montessori model characteristics are similar to the characteristics reported in the problem solving research which facilitate transfer?
2. In what ways does problem solving within the Montessori classroom transfer?
3. What are the factors that influence problem solving transfer in a Montessori classroom?
    - 3.1 What teacher instructional strategies influence problem solving transfer in a Montessori classroom?
    - 3.2 What student characteristics influence problem solving transfer in a Montessori classroom?
    - 3.3 What curriculum characteristics influence problem solving transfer in a Montessori classroom?

Glossary of Terms

Bureaucratic structure is a type of organizational structure that is characterized as stable, predictable, and standardized.

Domain is a field of study (i.e., mathematics, history, biology).

Knowledge transfer occurs when prior learning of task A affects new learning of Task B.

Metacognitive strategies refers to using skills such as planning, reflection and self-regulation in the thinking process.

Model is the ideal curriculum program.

Montessori is a model of education developed by Dr. Maria Montessori in the early 1900s. It is considered to be both a philosophy of child development and a methodology for facilitating learning.

Organic structure is a type of organizational structure that is characterized as dynamic, adaptive, and is not standardized.

Problem solving is a cognitive process aimed at achieving a goal when no solution is apparent to the problem solver.

Problem solving transfer occurs when a problem solver uses a prior experience with one kind of problem to solve a different kind of problem.

Program is an actual curriculum or course of study.

Transfer is the ability to take what has been learned and use that information to understand new information.

CHAPTER TWO

Literature Review

Many of today's elementary students will live in the decades of 2050 and beyond. They will probably be working at jobs that do not currently exist (Halpern, 1998). Perhaps as many as 60% of all new jobs in the 21st century will require skills that only 20% of the current workforce possess. Work that requires high level skill is quickly replacing unskilled jobs. Today an estimated 85% of all jobs are classified as skilled, whereas in 1950, 80% of all jobs were classified as unskilled (U.S. Department of Education, 2000).

Today's workplace environment is changing at an increasing pace because of rapidly evolving technology and the explosion of available information. Via the internet and other readily available sources, people have unlimited access to a wealth of information. However, as information multiplies, the problem becomes one of knowing what to do with all the data. If people do not know how to think and make decisions, they may have all the answers but will not know what it means or how to use the information. A quality education in the 21st century will teach students how to learn and how to think clearly about the myriad of issues they will confront in the workplace of tomorrow (Halpern, 1998).

No longer can teachers just dispense knowledge. They must function more as facilitators or guides, helping students locate, understand, and use information. The ultimate goal of education is to produce better thinkers who will transfer their learning beyond the classroom and into their professional lives (Davis, 1999; Halpern, 1998).

Currently, much of the knowledge that students acquire in school is inert or passive. It is usable only when students respond to direct probes such as multiple choice tests. The knowledge is seldom retrieved and applied to other contexts or situations. However, in optimum learning environments, students are not as concerned with finding a correct answer as they are with learning to think through a problem solving situation (Gersten & Baker, 1998).

The aim of education should be not only the acquisition of knowledge and skills but the transfer of that knowledge and skills. What students learn in school should enhance their thinking in other school subjects and in their life outside of school. Transfer plays an important role in the teaching of thinking skills.

Transfer is the "process of using knowledge acquired in one situation in some new or novel situation" (Alexander & Murphy, 1999, p. 561). Transfer can be described as a knowledge or skill associated with one context being used to enhance another context. More than ordinary learning, transferred knowledge has to travel across gaps to new contexts (Perkins & Salomon, 1989). Employers often complain that employees cannot think. In other words, these employees exhibit very little evidence of transfer (Byrnes, 1996).

Unfortunately, current conventional schooling pays little attention to transfer. Often students do not see a connection between what they are learning and "real life." If all students do in school is repetitive, low level work, they are not being educated to organize their thinking, and transfer of the material will not take place. Educators have mistakenly ascribed to the "Bo Peep Theory" of transfer (Byrnes, 1996). If you leave them alone, they will come home wagging their tails behind them. This is the assumption that whatever a student learns will automatically transfer whenever it is needed. No one actually advocates this, but many educators unknowingly practice it. Teaching students to learn to transfer information may be as important, if not more important, than teaching them knowledge and skills (Perkins & Salomon, 1989).

Having recognized the critical importance of the concept of transfer in the science of learning, researchers have historically studied the characteristics of transfer. The following section describes the perspectives on transfer which have dominated the field of cognitive psychology.

Views of Transfer

For centuries, psychologists and educators have been intrigued with the topic of transfer. Research on learning has produced four views of transfer: general transfer of general skills, specific transfer of specific skills, specific transfer of general skills, and metacognitive skills (Mayer & Wittrock, 1996).

General Transfer of General Skills

Prior to Thorndike and Woodworth's early work (1901) the prevailing belief was that transfer occurred when one's mind was strengthened. In other words, the training of basic mental functions leads to better skills which would transfer to new situations. According to this approach, a mind was like a muscle that needed to be exercised. Thus, exercising the mind by learning Latin or logic would help the student think better, and this better thinking would transfer to all other courses or situations. This general transfer of skills, known as the belief in "formal discipline" was predominant at the beginning of the 20th century.

Specific Transfer of Specific Skills

Thorndike (1901) conducted his early work on transfer with the intention of disproving the formal discipline educational approach. He showed that students did not do better in other subjects after learning Latin or logic. He argued that transfer only occurred when there were many similarities between the learning context and the transfer context. Transfer would occur when the specific content of one subject was needed to learn another subject. He concluded that no transfer takes place unless there are common elements. Mayer and Wittrock (1996) reported, "According to this specific transfer view, learning of A will help a person learn B only if B contains elements that are identical to A" (p. 50). Central to Thorndike's theory was the belief that the learner was a passive recipient of information (Campione, Shapiro, & Brown, 1995). His "identical elements" theory dominated research for the first sixty years of the 20th century (Campione, et al. 1995).

Specific Transfer of General Skills

Consistent with the specific transfer perspective, supporters of this view of transfer also believe that transfer occurs only when Task A and Task B require the same skills. However, the proponents of this view of specific transfer of general skills argue that the component that transferred from Task A to Task B could be a general strategy or principle, rather than a specific skill. According to this view, the understanding of how to solve one problem will help an individual solve a different type of problem even if the components are not identical in the two problems. Gestalt psychologists, including Judd, Katona, and Wertheimer constructed this theory of transfer (Mayer & Wittrock, 1996).

Metacognitive Skills

Metacognition is defined as the "awareness of one's own cognitive processing" (Mayer, 1992, p. 256). Halpern (1996) stated, "Metacognitive monitoring of your thinking process includes deciding which problems are worth working on, allocating time and effort to different problems and parts of problems, and keeping track of whether you are making progress toward the goal" (p. 28). The problem solver is actively using prior knowledge to solve a new problem.

Transfer occurs when the learner recognizes the cognitive processes needed, selects and applies the previous knowledge and skills that apply to the new learning, and monitors the progress toward the goal (Mayer & Wittrock, 1996). According to this view, lack of metacognition can cause transfer not to happen. Studies have shown that transfer is more likely to occur when the student is mindful and makes a conscious attempt to think about the learning process (Brown, Bransford, Ferra, & Campione, 1983).

In summary, much of the current research on transfer uses one or more of these views as a theoretical basis for further exploration. The issue of specific versus general skills, the effectiveness of mind broadening exercises, the importance of meaningful instruction, and the current emphasis on metacognitive strategies are prevalent topics in the transfer of learning literature (Mayer & Wittrock, 1996). The following studies on transfer illustrate this point.

Transfer Studies

Literacy is a powerful carrier of cognitive abilities. Many believe that a gain in literacy offers gains in the skills of reading and writing as well as general cognitive improvement. In 1981, Scriber and Cole studied an African tribe called the Vai. The tribe used a written language, but had no established formal schooling. Transfer did not occur. Learning the written language (literacy) had very little impact on other cognitive performance of the Vai. In different studies, chess players may have expertise in the game that depends, for the most part on their experience with the game. Proficiency in logic used in the game of chess does not carry over to other intellectual pursuits (Perkins & Salomon, 1989).

Learning computer programming requires a systematic approach such as breaking problems into smaller pieces and diagnosing the causes of difficulties. Therefore, researchers studied this type of thinking to see if the skill would transfer to other domains. The teaching of computer languages such as LOGO has been explored to determine if there was evidence of increased cognition. However, findings have shown that learning programming has failed to enhance cognitive skills and transfer (Mayer & Wittrock, 1996; Salomon & Perkins, 1987). Transfer tends to be domain-specific. A person who is highly skilled in one domain, such as chess, does not necessarily transfer that skill to a different domain, such as math (Byrnes, 1996).

Lave (1988) found transfer to be affected by the context in which the learning occurred. In research conducted with a group of homemakers, they were able to successfully do calculations to determine the best buys in a grocery store, but had trouble with similar math problems in a classroom setting. Homeless children in Brazil exhibited the same lack of transfer when asked to answer problems in school that resembled the same skills they used on the street to sell products (Carraher, 1986). Salomon and Perkins (1987) explored the concept of domain-specificity and coined the terms "low road transfer" and "high road transfer" to explain the transfer skills needed in similar and dissimilar learning situations.

Low Road/High Road Transfer

Salomon and Perkins (1987) provided the "low road/high road" model to explain the mechanisms of transfer. Low road transfer is similar to learning to drive a truck after having driven a car for quite some time. The new context of truck driving holds many similarities to the original context and automatically triggers a much practiced routine. This illustrates *near* transfer because the new learning situation is closely connected with the prior knowledge.

High road transfer involves purposeful contemplation geared toward extracting a skill or knowledge from one context to apply it in another. High road transfer, or *far* transfer, can be forward reaching if one thinks that what is being learned will be applied to future endeavors. High road transfer can also be backward reaching when one considers his own past experiences or knowledge to find a match with what is currently being learned. Based upon a review of the literature concerning transfer from Thorndike to the present, Singley and Anderson (1989) concluded that only a few highly questionable studies found evidence of far or general transfer. Most studies that successfully documented transfer observed near (low road) transfer rather than far (high road) transfer.

In traditional schooling, the conditions for low road transfer are met by chance and transfer may occur (Perkins & Salomon, 1989). However, teachers need to be more deliberate in teaching students to use high road transfer. One way to promote high road transfer is for teachers to point out the general principles behind skills or knowledge. Too often teachers get lost in focusing exclusively on the subject matter, fact-based knowledge (Byrnes, 1996). Although the classroom needs to provide a good foundation of knowledge in the context area, a strong curriculum also provides opportunities for encouraging transfer (Davis, 1999). Unfortunately, successful transfer is a more rare occurrence than educators would hope (Mayer & Wittrock, 1996).

Failure to Transfer

One reason that transfer does not occur is that students often tie the skill or knowledge to the context in which it was learned. Some scholars believe that a skill must first be decontextualized before it can be transferred (Brown, Bransford, Campione & Ferra, 1983; Singley & Anderson, 1989). The skill must be disembedded from the original learning context. If the information is presented in a variety of different situations, transfer is more likely to occur (Gagne, 1985).

Another reason that transfer, even of decontextualized skills or knowledge, does not occur may be because there is a gap between the knowledge and the desired goals. Byrnes (1996) stated, "If, for example, skills were never linked to appropriate goals in the original learning context, there would be no basis for using these skills in the transfer context" (p. 75). When the goal in the learning context, for instance, is "to finish my seatwork" but the goal in the transfer is "to know how much money to give the cashier," the goals of the two contexts are incompatible and transfer will not take place (Brynes, 1996).

Types of Knowledge

Up until this point in the review of the literature, the discussion has been on general transfer, sometimes referred to as "knowledge transfer" (Mayer, 1996). One way to think about learning is that previous knowledge is used to create new knowledge. "Everything we know, and everything everyone else knows--that is, all existing knowledge--was created by someone" (Halpern, 1996, p. 5).

Generally, knowledge is categorized into three types: declarative, procedural, and strategic (also referred to as conditional) (Davis, 1999; Gagne', 1985; Schunk, 2000). Declarative knowledge is the knowledge of facts, names, concepts, and events (Schunk, 2000). Gagne' (1985) referred to declarative knowledge as information that is verbalizable. He described three forms of declarative or verbal knowledge (a) names or labels (b) single facts and (c) collections of information that have meaning. Procedural knowledge is the knowledge of how to do something using rules, algorithms, and concepts (Schunk, 2000). The third type is conditional or strategic knowledge. This is the knowledge of "knowing when to employ forms of declarative and procedural knowledge and why it is important to do so" (Schunk, 2000, p. 82).

To be successful, students must possess not only the "knowing that" (declarative) and "knowing how" (procedural), but the "knowing when" (strategic) knowledge as well (Gunter, Estes & Schwab, 1999). All three types of knowledge can be relevant in defining what needs to be transferred as a function of a learning experience (Davis, 1999). However, having the declarative and procedural knowledge to perform a task does not automatically mean students will do it well. Strategic knowledge assists students in employing declarative and procedural knowledge to accomplish a task or to do problem solving (Schunk, 2000).

Problem Solving and Transfer

The remainder of this review will focus specifically on *problem solving* and *problem solving transfer*. The next sections will define problem solving and describe problem solving transfer.

Problem Solving

Mayer (1992) defined problem solving as cognitive processing aimed at achieving a goal when no solution method is apparent to the problem solver. According to his definition, there are several important characteristics.

1. Problem solving is a process which occurs within an individual's cognitive system (Mayer, 1992).
2. Problem solving requires representing and manipulating knowledge that is directed toward a goal (Mayer, 1992).
3. Problem solving is intensely personal because the prior knowledge and skill level of the problem solver determine the facility the person has for solving the problem (Mayer, 1992).
4. The problem solver has a goal but may not have an obvious method for reaching the goal (Mayer, 1992).
5. Problem solving can cover a wide range of problems from very broad to very specific (Lave, 1988; Scardamalia, Bereiter, & Goelman, 1982).

Types of Problems. In an article on intelligence, Maker (1992) described a conceptual framework for types of problems that was first proposed by Czikszentmihayi. Problem situations were categorized according to three characteristics, "(a) how clearly and completely the problem is stated, (b) how much of the method for reaching the solution is known to the solver, and (c) how general the agreement is about an acceptable solution" (Maker, 1992, p. 14). There are five problem types arranged in a continuum.

At one end of the continuum is a Type I problem in which the problem, method, and solution are all known to the presenter and the solver. The solver just uses the right steps to reach the correct solution. With Type II problem situations, the problem, method, and solution are known to the presenter, but the method and solution are unknown to the solver. Type III problems have a range of methods and solutions. In Type IV, the method and solutions are unknown to the presenter and solver. Type V problem situations are at the other end of the continuum. The problem, method, and solution are all unknown to the presenter and solver (Maker, 1992).

Teachers are more likely to teach critical thinking and problem solving with problems that are a Type I or II. These types of problems are clearly stated, methods for solving are known, and the solutions are known to the teacher. However, problems are usually not so clearly defined or solvable outside the classroom. They tend to more closely resemble Type IV and V problem situations (Maker, 1992).

Problem Solving Transfer

When a student uses problem solving skills learned in a previous situation to solve new and different problems, transfer has occurred (Mayer, 1999). Mayer and Wittrock (1996) defined problem-solving transfer in this manner:

> When a problem solver uses a previous experience with one kind of problem to help solve a different kind of problem. . . . Prior experience is measured by performance on task A (e.g., percent correct or type of method used on solving old problems) and new problem solving is

> measured by performance on task B (e.g., percent correct or type of method used on solving new problems). . . . Problem-solving transfer occurs when a student who has been taught how to solve two-step word problems to 100 percent accuracy is subsequently able to solve three-step word problems better than a student who was not taught two-step problems (p. 48).

There have been studies conducted to better predict and explain problem solving transfer. These are discussed below.

Problem Solving Transfer Studies

Researchers deduced that problem solving tends to be specialized and the rarity of transfer has been continually confirmed in laboratory studies (Gick & Holyoak, 1983; Mayer & Wittrock, 1996; Salomon & Perkins, 1989; Singley & Anderson, 1989).

Gick and Holyoak (1980, 1983) presented their subjects with a medical problem involving radiation after the participants had read a story about an unrelated military problem and its solution. Only about 30% of the participants realized that the radiation problem was analogous to the military problem and transferred what they learned from the military problem to solve the medical problem. However, transfer was greatly increased by merely suggesting to the participants that they make use of the military problem in solving the target problem. The study results indicated that the amount of transfer that occurs depends upon where the attention of the subject is directed. Studies in which learners were encouraged to think about the potential of transfer and the use of multiple examples have been conducted (Brown & Kane, 1988; Ghatala, Levin, Pressley, & Lodico, 1985; Stark, Mandl, Gruber & Renkl, 1999).

Stark et al. (1999) described two experiments conducted on business students that examined a variety of instructional variables which fostered transfer. In a computer-based simulation, the students investigated the effectiveness of multiple learning contexts which involved three different market situations and multi-staged problem solving guidance. The second study examined the learning of accounting principles by using either multiple worked-out examples or a guided example elaboration technique. Stark et al. concluded that the use of complex learning environments or techniques need to be carefully considered. Multiple learning conditions with additional support for the students achieved transfer, whereas without the support students were overwhelmed and transfer was poor.

A number of studies exposed the limitations on the ability to transfer. For example, when students lacked a conceptual understanding of a skill, they were less likely to exhibit transfer (Mayer, 1989). In a study by Wertheimer in 1945, one group of children was shown how to perform the drop-perpendicular technique for computing the area of a parallelogram. In other words, they learned it by rote. Another group was also shown how to perform the drop-perpendicular technique but in addition they were given an explanation as to why the method worked. When all of the children were presented with a problem involving a parallelogram in an unusual orientation, the group who had received the additional explanation easily adjusted the method to fit the new orientation whereas children in the rote-learning only group used the method inappropriately.

Singley and Anderson (1989) found that the amount of transfer is related to the degree to which the tasks share cognitive elements. After teaching participants, 24 women in a secretarial school, how to use several text editors, they presented them with a new editor that had not been taught. The findings showed that the number of similarities in procedural elements of text editors predicted the amount of transfer that took place. The authors referred to this as lateral transfer which is defined as "transfer between skills at the same level of compexity" (Singley & Anderson, 1989, p. 68).

In the past, documenting educational experiences that promote problem-solving transfer has been difficult. Although learning to use educational software has often been suggested as a way of achieving such a transfer of cognitive skills, there has not been much hard evidence to that effect. The purpose of the study, *What is Learned in an After-School Computer Club* (Mayer, Quilici, & Moreno, 1999) was to test the cognitive transfer hypothesis to see whether "exposure to certain kinds of educational computing environments can transfer to improved cognitive processing in different situations" (p. 225). Toward that end, this study examined the cognitive consequences that participation in an informal educational environment, such as an after-school computer club, had on the transfer of problem-solving skills to learning in a school environment.

Fifty elementary children from southern California, most whose first language is Spanish, were chosen to participate in this study. Half of the children were in the treatment group and half were in the control group. Those in the treatment group were invited to participate in an after-school computer club in where they learned to use a variety of education programs. The learning task for all of the children was to solve a series of three novel mathematical puzzles.

The three novel puzzles were a paper-and-pencil version of a mathematics computer game called Puzzle Tanks. The hypothesis was that the treatment group would learn generalizable cognitive skills in the computer club that would transfer to solving these novel puzzles. The researchers predicted that the children in the treatment group would produce fewer errors and, in focusing on the quality of their performance, children in the treatment group would invent more sophisticated solutions than would the control group when solving these puzzles.

As predicted, the treatment group had fewer errors in completing the learning task than did the control group, and they invented more sophisticated solution strategies. The findings of this study provided evidence that students can learn cognitive skills in an informal educational environment that transfer to learning in a school environment. The children in this study learned content-specific skills (math) as well as computer-specific skills, and they also developed skill in learning how to learn.

According to the authors, further research is needed to pinpoint which aspect or aspects of the after-school club promoted the problem solving transfer: experience using educational computer software, working with peers or mentors, or some other aspect of the club. However, this research supports the theory that generalizable problem solving skills can transfer to learning in another environment.

Multimedia learning environments are those in which instruction is presented in a variety of different ways, both visually and verbally. These types of environments can promote learning that enables problem solving transfer (Mayer, 1999). Based on this contention, a number of laboratory studies were conducted using college students. These students (subjects) were unfamiliar with the topic for which a multimedia message was provided. The message contained scientific or mathematical explanations and students were assessed using tests of problem solving transfer.

In nine different studies, subjects were exposed to a variety of computer based explanations, such as how brakes work and how bicycle pumps work. Comparisons were made between explanations presented only with on-screen text and those with both on-screen text and animation. The rationale for using multimedia methods is that learners understand better what they see in words and pictures than just words alone.

The studies showed that students who received messages experienced an 87% gain in problem solving transfer over the single media group. Therefore, the conclusion was that the addition of pictures to the words increased the subjects' ability to use material in problem solving transfer; it appeared then that students were better able to integrate verbal and visual representations when they received multimedia messages. When only single media (words) were presented, the student constructed a visual model that was insufficient to integrate fully with the verbal model. Although these studies suffer from the limitations of using only college students and laboratory settings, they do suggest that well designed mutimedia presentations can assist learners in understanding material that enhances their problem solving transfer capabilities (Mayer, 1999).

In another study of 141 college freshman at a Flemish university, Masui and Decorte (1999) attempted to stimulate the integration of metacognitive, affective, and cognitive activities in learning and problem solving. An integrated set of instructional conditions was operationalized in a series of sessions involving practice and transfer tasks. Masui and Decorte (1999) concluded that teaching students to be more self-regulated improved both academic success and transfer behavior and that both metaknowledge and transfer behavior are positively related to academic performance.

Campione and Shapiro (1995) brought subjects into a laboratory and presented them with a sequence of two tasks, usually back-to-back. During the first task, subjects were taught something such as a response, rule, or principle. They were then observed performing another task with features similar to the one on which they had received the instruction. If problem settings appeared to be the same, transfer was more likely to occur. If they appeared different, transfer was not likely to occur. These effects were observed across a wide range of ages and abilities (Campione, 1973; Campione & Brown, 1973, 1974).

Generally, if someone understands the principle involved, transfer is likely or if learning can be organized around a guiding principle, transfer is affected by the extent to which the learner understands the principle. In training studies in the 1970s involving young or academically delayed children, researchers (Brown, 1974, 1978; Campione & Brown, 1977, 1978) found that students exposed to memory task models made impressive improvements on a variety of memory tasks. However, when asked to apply what they had learned to a novel task, they acted as if the training had not occurred.

Other authors, such as Brown and Kane (1988) did find that their subjects, children 3-5 years old, could be successful in transferring across task boundaries. The children were successful when they were (a) given experience and practice with a series of pairs of analogous problems, or (b) told to adhere to the goal structure of the original problem, or (c) asked to think about similarities between the pairs of problems, or (d) required to teach others what they had learned

(Campione 1995). Because laboratory experiments have their limitations--that is transfer must be demonstrated in a specific way as determined by the person conducting the experiment--transfer capabilities in subjects, particularly children, may be underestimated (Campione, 1995).

Transfer Within Classrooms

In their chapter in *Teaching for Transfer*, Campione, Shapiro, and Brown (1995) discussed their efforts to redesign classrooms to better foster "communities of learners." They acknowledged, however, the difficulty in recognizing transfer in the context of classrooms. Transfer is essentially a theoretical term that has been applied to a range of phenomena. It is not always evident how to operationalize transfer in a "real setting."

The authors noted that it is virtually impossible to extend laboratory protocols into a classroom environment. Conducting research on transfer in naturalistic settings, like an elementary classroom, presents challenges not faced in controlled laboratories. Thus, research on transfer in the classroom is very difficult. One reason is that the learning that leads to transfer occurs over an extended period of time. Also, learners may exhibit transfer in a variety of ways, and at times it may not be expected. These facts pose many methodological challenges for the researcher. If the classroom permits multiple changes from the norm, it becomes very difficult to maintain controls.

For their research, Campione and colleagues (1995) organized the classroom to encourage students to master a wide domain of knowledge. The activities were structured so that the students were compelled to use what they learned to discover new knowledge within that domain. In addition, instruction and modeling were provided to help students develop critical thinking skills and reflection activities that can guide future learning in new areas. Reading and writing were an integral part of both communication and knowledge building. Finally, the students were encouraged to spend time exploring the features and limitations of what they learned and the reasons they were undertaking the activities. In other words, they were encouraged to engage in metacognition.

Another critical component of the community of learners model is the classroom culture. The culture should foster responsibility and ownership for learning and mutual respect between students and between teachers and students. The model emphasized (a) constructive discussion and questioning, (b) a highly structured, ritualistic classroom, and (c) enough repetition to free students to focus their energy on the more complex cognitive tasks (Campione et al. 1995).

These authors' view is that there are many ways that students transfer knowledge. These range from understanding domain-specific concepts to employing domain-general reading and argumentation strategies. They emphasize both the use of concepts and strategies and the ability of the student to use and explain them to themselves and others. Therefore, Campione, Shapiro and Brown (1995) have defined transfer as *understanding*. "Understanding is indexed by the ability of learners to explain the resources (knowledge and processes) they are acquiring and to make flexible use of them" (p. 39).

Campione et al. (1995) attempted to capture and enhance transfer as it manifests itself in an elementary classroom. Their findings have shown higher degrees of transfer in classroom than in the control group environment. The authors attributed the increased incidence to (a) the expanded definition of transfer, (b) the use of metacognitive factors, (c) the emphasis on a collaborative learning environment, (d) the classroom culture, and (e) the extensive analysis of the content being studied.

In conclusion, recent advances in cognitive psychology have increased understanding of learning and transfer as well as the conditions necessary for transfer to occur. Few studies have been successful using the general skills view, known as "formal discipline." The associationism view of specific transfer of specific skills has met with some success when the objective was the transfer of specific basic skills. However, this view has not addressed the issue of how to teach general skills. The more successful views of the specific transfer of general skills and metacognitive approach indicate that problem solving transfer can be improved. Results from the transfer studies described in this review indicate that teaching through meaningful instruction and metacognitive strategies will enhance transfer.

Factors That Contribute to Problem Solving Transfer

Recent research has indicated that certain instructional strategies encourage problem solving transfer and have a positive effect on the quality of the process. Additional factors such as the individual's level of intelligence and the influence of the teacher have also proven to be influential on student problem solving and transfer.

Instructional Strategies

The variety of the learning opportunities, the quality of the learning, the depth of the learning, and metacognitive awareness are the four strategies discussed below.

Variety of learning opportunities. Sometimes referred to as "multiple knowledge representations" (Brenner et al. 1997), this means presenting information from a variety of perspectives and applications. Research has indicated that the more closely problems are related, the more likely transfer will occur (Riley, Greeno, & Heller, 1982). Therefore, multiple problems that look dissimilar but are similar in strategies and goals are recommended. This variation encourages transfer through decontextualization of the learning. By eliminating links between skills and irrelevant aspects of contexts and forming links between skills and various contexts to which those skills can be applied, transfer is encouraged (Byrnes, 1996). Students are more likely to transfer information learned from a specific problem if they understand that the solution is an example of a general method (Greeno, Collins, & Resnick, 1996). Thus, students recognize the generalizability of the solution. An instructional emphasis on the development and explanation of problems and solutions will enhance transfer (Resnick, 1987).

Quality of learning. Quality refers to how meaningful the learning is for the learner (Brooks & Dansereau, 1987; Mayer, 1987). According to cognitive psychologists, meaning has to do with the way a concept is embedded in a web-like array of related concepts. The more connections to other concepts, the richer the meaning of the information (Halpern, 1998). Instructional methods such as discovery learning, using concrete manipulatives, and generating relationships are designed to encourage meaningful learning (Mayer & Wittrock, 1996).

Elaboration assists in organizing concepts in a meaningful way. Using thoughtful questions that require the learner to make connections between the various concepts is particularly effective. Questions based in contexts that are known by the learner are powerful. Good learning environments facilitate real-life thinking (Halpern, 1998).

High quality problems have applications and are relevant to the problem solver's life. Problems identified or generated by students are particularly powerful (Eggan & Kauchak, 1999). Meaningful, problem-based activities lead to accomplishment in relevant areas and are not just exercises. Furthermore, the learner needs to be shown how the knowledge or skills that they learn in a particular situation can be utilized in other contexts (Alexander & Murphy, 1999).

In order for learning to have meaning, learners must engage in active cognitive processing. They must be able to select relevant information, organize the information into meaningful representations, and make connections between old and new knowledge (Mayer & Wittrock, 1996). To truly understand, a learner must be able to link pieces of information and be able to see why or how different sets of information are linked (Gersten & Baker, 1998).

Depth of understanding. The more time spent learning to solve problems (Gick & Holyoak, 1987) and the more opportunities learners have to practice (Cormier, 1987), the more likely problem solving will transfer. Brophy (1992) discussed the importance of depth of understanding versus the acquisition of content knowledge. To expect transfer it is necessary to teach the underlying principle rather that just facts. Alexander and Murphy (1999) stressed that transfer is not enhanced by the simple accumulation of rote facts and knowledge.

A new report from the National Academies' National Research Council urges educators of advanced high school courses in mathematics and science to "focus on helping students acquire in-depth understanding rather than the more superficial knowledge that comes from covering too much material too quickly"(Vines, 2002, p. 1). The co-chair of the Research Council committee that wrote the report stated:

> The primary aim of programs such as Advanced Placement and International Baccalaureate should be to help students achieve deep understanding of the content and unifying ideas of a science or math discipline. In advanced chemistry, for example, students should not only explore the atomic nature of matter, but also learn how it can explain chemical bonding that holds molecules together, as well as the widely varying tendency of different materials to react. On the whole, well-designed advanced programs must provide opportunities to experiment, critically analyze information, argue about ideas, and solve problems Gollub, 2002, p. 1).

The basis for transfer is rooted in a cohesive and comprehensive body of knowledge. Opportunities for discussion and sharing of ideas facilitate transfer (Vanderstoep & Siefert, 1994).

Metacognitive awareness. Metacognition, the self-awareness of one's own thinking processes increases the chance for transfer (Brown & Kane, 1988; Mayer & Wittrock, 1996; Perkins & Salomon, 1988). Transfer is more likely to occur when the student is mindful and makes a conscious attempt to think about the learning process (Brown, et al. 1983). Expert problem solvers use metacognitive strategies such as reflection. "Reflection is thinking about what happened during learning and problem solving as well as thinking about the factors that influenced the process and outcome" (Masui & DeCorte, 1999, p. 519). Perkins and Salomon (1989) regarded reflection as a key metacognitive tool in the "high road to transfer."

Halpern (1998) proposed a strong metacognitive model for teaching thinking skills to encourage transfer. Students need to be taught to monitor their thinking while working toward an appropriate goal. They need to learn how to make decisions about their use of time and cognitive effort.

Another strong influence on transfer is the student's orientation to the learning (Prawat, 1989). How students approach or deal with situations is influenced by their dispositions. Katz and Raths (1995) referred to dispositions as "habits of mind." Dweck and Elliott (1983) proposed that the disparity between what people normally do and what they are capable of doing in ideal situations depends upon their dispositions. According to Halpern (1998), when students approach tasks with an open mind and persistence they are more likely to engage in critical thinking that will transfer across domains.

Intelligence

In recent years, research has addressed the positive relationship between intelligence and problem solving. Sternberg (1994) stated, "Most researchers agree that the definition of intelligence includes some element of novel problem solving" (p. 963). The ability to transfer skills is considered to be "a good predictor of how responsive the child will be to instruction" (Sternberg, 1994, p. 370). Research indicates that gifted individuals have specific cognitive abilities such as transferring knowledge across domains, focusing on relevant information, and using knowledge and strategies for problem solving (Johnsen, 1997). In addition, Wagner and Sternberg (1990) presented evidence of a positive relationship between practical intelligence and practical problem solving such as tasks found in simulated work environments. Therefore, one could hypothesize that the higher a student's level of intelligence, the greater the student's ability to problem solve and to transfer the knowledge.

Teacher Influence

Vygotsky believed that psychological processes begin within a social context and stressed the importance of adult-child relationships in developing the zone of proximal development theory (Sternberg & Detterman, 1979). He defined the zone as "the distance between the actual development level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (Vygotsky, 1935/1978, pp. 85-86).

Self-efficacy. Bandura (1977) described the importance of modeling and learning by vicarious experience. Currently, researchers recognize the importance of teaching metacognitive strategies to enhance problem solving transfer, including skills such as planning, reflection, and self-regulation, which is an awareness of the thinking process (Armstrong, 1989; Mayer & Wittrock, 1996). Students need to be aware of cognitive strategies and when to use them (Brown & Pressley, 1994; Armstrong, 1989).

Good problem solving benefits from metacognitive awareness (Pintrich & DeGroot, 1990). Bandura's theory on self-efficacy indicates that, when an individual experiences success with problem solving, he/she tends to have high efficacy which leads to trying harder and solving more problems (Schunk, 1994).

Questioning strategies. It has been suggested that using metacognitive strategies will facilitate problem solving transfer (Mayer & Wittrock, 1996). Structuring questions well enables students to reflect on their learning and may give them insights that will assist in thinking critically (Halpern, 1998). Evidence from the Friedman and Lee study (1996) indicated that the higher the level of questioning of teachers, the higher the level of response of the students. In their study, The Flanders Interaction Analysis Categories-Modified (FIAC-M) was developed for the purpose of evaluating the training components of three models of gifted education. The FIAC-M was modified from the Flanders Interaction Analysis Categories (FIAC) (Flanders, 1970). The FIAC was originally designed as a tool for identifying, cataloging, and analyzing teacher-student instructional interactions.

The modified instrument, FIAC-M, categorizes teacher questions and student responses in cognitive complexity according to Bloom's Taxonomy of Educational Objectives (1956). This cognitive taxonomy classified knowledge and understanding on the basis of increasing complexity from memory to higher-order operations. The six levels of Bloom's taxonomy are knowledge, comprehension, application, analysis, synthesis, and evaluation. The first two levels knowledge and comprehension, are lower level while the remaining four levels are higher-level because they require more complex types of thinking (Parson, Hinson & Sardo-Brow, 2001). In the 21st century, as student problem solving is increasingly emphasized, the goal for higher-level thinking becomes more important (Eggen & Kauchak, 2001).

Metacognitive knowledge. Recognizing the importance of possessing metacognitive knowledge and strategies, the teacher can be a critical factor in enhancing a student's problem solving ability and transfer. Unfortunately, many teachers have not been trained in metacognitive strategies nor do they possess good thinking skills. Teachers lacking problem solving skills may have low self-efficacy in their ability to teach problem solving and therefore, not believe they can affect student learning necessary for problem solving transfer.

Knowledge of domain. Also indicated is the importance of teachers possessing strong content knowledge in their fields in order to make thoughtful decisions about classroom instruction. When teachers are grounded in their knowledge, they have the ability to relate the content to concepts and key principles. Thus, they are modeling the process of transfer (Alexander & Murphy, 1999). Teachers must use linking and transfer as part of their presentations in order to enable their students to do so. "If you want students to engage in analogical thinking and to manifest transfer, then become the very model of that process" (Alexander & Murphy, 1999, p. 573). Educators should not expect students to be able to do what the teacher cannot do.

Teaching strategies. Selecting the appropriate teaching methods, sometimes referred to as strategies, is also a very important task for educators. There are numerous teaching strategies. As explained by Tomlinson, et al. (2002), "Teacher comfort and competence with each method is valuable, but more valuable is a teacher's ability to match the instructional knowledge technique with learning goals and to provide structure, guidance, and support for student success" (p. 53). These authors described 21 teaching methods, which are organized with those methods that are more teacher directed and allow less student inquiry and independence (i.e., lecture, drill and instruction, and direct instruction) at the top of the chart. As the chart continues, the methods are increasingly more student centered and encourage more student inference and independence. For example, strategies such as inquiry-based instruction, problem solving and problem-based learning, and independent study are at the bottom of the chart. Teachers should vary the methods to "promote student engagement and higher order thinking" (Tomlinson et al., 2002, p. 56).

In conclusion, the field of cognitive psychology has provided many insights into how individuals learn and problem solve, but there is a pressing need for additional study on how educators can better prepare students for the complex world. Although Montessori education emphasizes independent thinking and problem solving, no studies have examined the effectiveness of the model.

Montessori Philosophy

Maria Montessori, the first female medical doctor in Italy, was born in 1870 and died in 1952. She lived her life in Italy, Spain, India, and the Netherlands during the two World Wars. During her life she studied children, developed schools, gave lectures, and trained teachers. Her life was devoted to understanding children and how to facilitate their learning. She believed the goal of education was to contribute to the development of a complete human being who adapts to his or her time, place, and culture (Lillard, 1996).

Dr. Montessori's educational approach was based on observations of children from many cultures. Therefore, she believed her principles provided a foundation for educational programs throughout the world. Her philosophical ideas are based on three main points:

1. Human development does not occur in a straight line but in a series of formative stages of development;
2. The development of human beings is influenced by one's actions and environment;
3. Development is enhanced when individuals are given the freedom to follow their own interest (Lillard, 1996).

Following these general principles, a Montessori classroom is a highly structured, prepared environment. All the materials in the classroom are part of a curriculum that provides consistency through an orderly sequence and logical progression.

An integral component of the Montessori approach is the teacher. The Montessori teacher is trained to be an observer of children and to understand the theories of child development. Teachers are taught to match appropriate skills and activities to the child's developmental level. The materials are designed to facilitate development in all three areas of development: physical, cognitive, and social-emotional (Coe, 1991).

Although the Montessori model of learning has existed for almost a hundred years in the United States, there has been very little research conducted on the effectiveness of this educational approach. Crain stated, "Good studies are scarce, and they are not terribly conclusive" (Crain, 2000, p. 83). The following summarizes the empirical research on Montessori in elementary school settings.

Research on Learning in Elementary Montessori Classrooms

Recent studies on the Montessori model of instruction in elementary schools have used achievement test results as a barometer of learning effectiveness. Fero (1997) examined the academic achievement scores of students in grades two through five who were taught with the Montessori method of instruction and students who were taught with traditional methods of instruction in the Helena, Montana Public School District. Students who had been in a Montessori classroom for at least two years were matched with a student from the district who was in a traditional classroom. A total of 120 students who were matched on grade level, gender, aptitude, handicapping conditions (if present) and family socioeconomic status variables participated in the study. Aptitude was measured by The Test of Cognitive Skills (CTB, 1993) and The Comprehensive Tests of Basic Skills (CTB, 1993) was the achievement measure.

The achievement test results indicated no significant findings at the third and fourth grade levels. At the second grade level, Montessori students scored higher than traditional students in vocabulary. At the fifth grade level, Montessori students scored significantly higher in language expression and social studies. Overall, students in the traditional classrooms scored significantly higher in mathematics computation and concepts. Fero (1997) concluded that comparable test results were achieved with the Montessori method of instruction and the traditional method of instruction.

Other recent studies (i.e., Cisneros, 1994; Duax, 1995, Moore, 1991) evaluated the effectiveness of the Montessori model of instruction using achievement test measures. These studies have also been met with mixed results. In some findings the Montessori method of instruction led to more favorable results on achievement tests and in other findings, the students in non-Montessori classrooms achieved higher achievement test results. As Cisneros (1994) concluded, students in Montessori classrooms achieve at a rate equal to or greater that those taught in traditional classrooms in some subject areas, but not in others.

It is difficult to know if the effects described in these studies were due to the model of instruction or to other factors such as poor quality research, lack of research controls, non-randomized groups, or poor teacher training. Regardless, Montessorian educators have argued that achievement tests do not accurately capture the essence of what is taught and learned within a Montessori classroom. E. Coe (personal communication, May 1, 1998) did not believe that achievement test results capture the critical thinking and problem solving skill that is taught in a Montessori classroom. Furthermore, Maria Montessori cared little about students' success on achievement tests. "She wanted to unharness their natural love for learning and their capacities for concerted and independent work" (Crain, 2000, p. 83).

CHAPTER THREE

Research Design and Methodology

The U. S. Department of Labor has charged the education community with preparing students for the 21st century. Problem solving is one of the primary skills necessary for tomorrow's workplace (U.S. Department of Labor, 1991). Not only do students need to know how to think, they need to know how to transfer knowledge learned in one setting to a variety of problem solving situations (Van Tassel-Baska et al. 1988). Ultimately, students need to be able to apply the knowledge learned in the classroom to their everyday lives and to their future job performance (Greeno, Collins & Resnick, 1996).

However, some researchers are skeptical that transfer can be taught or even exists. In their seminal piece on problem solving transfer, Mayer and Wittrock (1996) stated, "...the search for teachable aspects of problem solving is not complete" (p. 59). However, they did conclude, "Armed with an array of cognitive theories that did not exist a generation ago, educational and cognitive psychologists have begun to understand the conditions for transfer "(p. 59). Therefore, this study focused on the following questions:

1. What Montessori model characteristics are similar to the characteristics reported in the problem solving research that facilitate transfer?
2. In what ways does problem solving within the Montessori classroom transfer?
3. What are the factors that influence problem solving transfer in a

Montessori classroom?

3.1 What teacher instructional strategies influence problem solving transfer in a Montessori classroom?

3.2 What student characteristics influence problem solving transfer in a Montessori classroom?

3.3 What curriculum characteristics influence problem solving transfer in a Montessori classroom?

Research Design

Miles and Huberman (1994) described a case as “a phenomenon of some sort occurring in a bounded context” (p. 25). Merriam (2001) defined the case as, “a thing, a single entity, a unit around which there are boundaries” (p. 27) that is “particularly suitable design if you are interested in process” (p. 33) and “plays an important role in advancing a field’s knowledge base” (p. 41). Given the nature of this research, the questions were addressed through a case study design.

The case study was the best design for this research. In reference to Miles and Huberman’s (1994) and Merriam’s (2001) definitions: (a) The unit of study is a fourth through sixth grade level Montessori classroom; and as such, there are naturally defined boundaries around this “single entity;” (b) the focus in this research was on the process students and teachers employ when problem solving and transferring skills in a Montessori classroom; and (c) there is a need to contribute to the knowledge base on problem solving and transfer, particularly by studying the phenomena with elementary-aged students in a naturalistic setting.

Site for the Study

The site for this research was a private, non-profit Montessori school for toddlers through sixth grade. The school is located on a tree-lined street in an older neighborhood. At the time of the study, the school campus consisted of two buildings with a total enrollment of 225 students. In the elementary building there were three classes of 6-9 year olds (first through third level) and two upper classes of 9-12 year olds (fourth through sixth level). Each elementary class had two teachers and a maximum student-teacher ratio of 12:1.

The elementary teachers had four-year degrees in education or a related field, and the lead teachers were certified in Montessori education. Their teaching experience ranged from fifteen years to one year in the classroom. The school was affiliated with the American Montessori Society and served as a training site for a joint master's degree with Montessori certification program offered through a local university and a regional Montessori training center.

The researcher was very familiar with this school and had easy entry into the site to conduct the study. Her son had graduated from this school a year prior to the beginning of the study, and she had a professional relationship with many of the teachers.

The School's Mission

The school's mission statement as stated in the Parent Handbook (1997) was:

> To provide the highest quality learning environment . . . while offering the child a Montessori approach to learning which provides tools for independent learning, self-discipline and respect for oneself and others. The aim of a Montessori education is to foster competent, responsible, adaptive citizens who are life-long learners and problem solvers (p. 2).

The school's belief statements included, "The integrated curriculum requires a schedule that includes large blocks of uninterrupted time to establish interdisciplinary connections to problem solve and to create new ideas (Parent Handbook, 1997, p. 2). Therefore this site was a good environment for the study because the ability to problem solve is a component of the school's mission, as well as the belief statement.

Participants

Participating in this study were 16 students, two teachers, and one parent of each of the students in a multi-aged, fourth through sixth grade level class at the Montessori school. Selecting these participants represented purposeful sampling. "The logic and power of purposeful sampling derive from the emphasis on in-depth understanding . . . the purpose of purposeful sampling is to select information-rich cases whose study will illuminate the questions under study" (Patton, 2002, p. 46).

This upper level, elementary age group was chosen because the majority of these students had been schooled in the Montessori model of learning for a number of years. Many of these students entered the school at age three. The class had a total of 20 students; however, four of the students were not included in the study because their parents did not give consent for them to participate. Of the 16 students, eight were girls and eight were boys. Five of the students were fourth grade level, six were fifth grade level, and five were sixth grade level. All of the students were Caucasian and from middle to high-income families. At the time of the study, the students' ages ranged from 9 years, 2 months to 11 years, 11 months.

The lead teacher for the class has an undergraduate degree in music and a master's degree in education. She is certified in Montessori education in both first-third and fourth-sixth grade levels and had been teaching for four years. The assistant teacher had taught for many years in elementary schools, with the last few in a Montessori classroom. This was her second year in this classroom. She was not Montessori certified but had an undergraduate degree in education.

Instruments

The data collection for this case study consisted of qualitative and quantitative measures. The analysis focused on those characteristics and factors that were found across the three data sources.

Qualitative Data

The following qualitative data collection procedures were used:

Semi-structured interviews. Individual, semi-structured interviews were conducted by the researcher with all of the students and at least one interview with one parent of all the students. Both classroom teachers were interviewed. Semi-structured interviews allowed the researcher to begin with specific questions but to deviate from those questions to follow a line of thinking presented by the respondent (Grady, 1998).

The researcher gathered information related to learning, problem solving and transfer within the Montessori model of instruction and applications within and outside the classroom. For example, questions such as "How do you learn new information in class?" and "Can you think of a time when already knowing something has helped you to learn something new?" were asked of the students. Two questions teachers responded to were: "How do you know students are learning?" and "Please describe situations when students have used previous knowledge to understand something new." Parents were asked to (a) describe the Montessori model of learning, and(b) to describe situations or conversations when their child had related information they learned in class to something outside of the classroom. These interviews were in-depth because there "...is an interest in understanding the experience of other people and meaning they make of that experience" (Seidman, 1991, p. 3). A copy of the interview questions is included in the Appendix.

Videotaped lessons. From November to May of the school year, twenty-six lessons were videotaped. The purpose of the videotaping of the lessons was twofold (a) to document the presence of instructional strategies and teacher characteristics that are similar to those that research suggests facilitate problem solving and problem solving transfer, and (b) to document the occurrence of problem solving and problem solving transfer within the classroom.

Document analysis. Relevant documents (i.e., the fourth through sixth grade level Montessori curriculum, students' lesson plans, students' work) were examined that related to the Montessori model characteristics and problem solving.

Quantitative Data

The following types of quantitative information were gathered:

Problem Solving and Thinking Processes. Due to the relationship between self-efficacy and problem solving, The Problem Solving and Thinking Processes scale was administered to the students and the two teachers at the beginning of the study. This thirty item instrument measures three aspects of problem solving: problem solving efficacy, metacognition or awareness of thinking, and enjoyment of thinking and problem solving. Each sub-scale contains ten items.

The instrument was developed for a dissertation study, *The Effect of Self-Regulation on Efficacy and Problem Solving* (Armstrong, 1998). Internal consistency was established with reported coefficients for the subscales of .91 for efficacy, .80 for metacognition, and .85 for enjoyment of thinking and problem solving. The overall reliability coefficient for the scale was .94.

Flanders Interaction Analysis Categories-Modified. The Flanders Interaction Analysis Categories-Modified (FIAC-M) was used in analyzing the teacher-student and student-student instructional interactions. The Flanders-Modified measures the level of cognitive complexity in the interactions. Evidence has indicated that the higher the level of questioning of the teachers, the higher the level of response of the student (Friedman & Lee, 1996). In addition, research has suggested that using metacognitive strategies will facilitate problem solving transfer (Mayer & Wittrock, 1996). The questions and responses of the teachers and students in each of the video-taped lessons were evaluated using the FIAC-M.

TONI-3: Test of NonVerbal Intelligence, 3rd Edition. Because of the strong relationship between intelligence and problem solving, the TONI-3 (Brown, Sherbenou & Johnsen, 1997) was individually administered to all the students. Problem solving ". . . underlies all intelligent behavior and it reflects the level of intellectual functioning of the problem solver" (Brown, Sherbenou & Johnsen, 1997, p. 30). The TONI-3 is a nationally standardized measure of cognitive ability with a strong emphasis on problem solving. According to the Examiner's Manual (1997), "The TONI-3 taps a single intelligent behavior, namely a person's ability to solve novel, abstract problems" (p. 29). The TONI-3 has a high degree of reliability and validity with the following results reported: overall reliability coefficient of .96 for both Forms A and B and criterion-related validity correlation coefficients ranging from .63 for the TONI-3, Forms A and B and the WISC-III to .73 for the TONI-3, Form A and the WAIS-R.

Academic engaged time observations. Academic engaged time (AET), defined as on-task behavior of all students (Friedman & Lee, 1996) was measured using the Engagement Check (McWilliam & Maher, 1999). The Engagement Check is an observational tool that measures group engagement. The Check determines the percentage of children engaged during activities. As defined in the Friedman and Lee (1996) study, examples of students' academic engagement could be their actively working on an instructional activity, interacting with the teacher or other students, or reading lesson materials.

Observations were conducted in the classroom using the Engagement Check (McWilliam & Maher, 1999). Previous research (i.e., Brophy, 1992; Cormier, 1987; Gick & Holyoak, 1987; Vanderstoep & Siefert, 1994) has indicated that the amount of time learning and the opportunities for instructional interaction contribute positively to learning and transfer. Table 1 presents the guiding questions and the instrumentation for this study.

Table 1

Guiding Questions and Instrumentation

Guiding Questions	Instrument
1. What Montessori model characteristics are similar to the characteristics reported in the problem solving research that facilitate transfer?	Interviews, video-taped lessons, documents
2. In what ways does problem solving within the Montessori classroom transfer?	Interviews, video-taped lessons, documents
3. What are the factors that influence problem solving transfer in a Montessori classroom?	
3.1 Teacher factors	Interviews, video-taped lessons, Problem solving scale, Flanders
3.2 Student factors	Interviews, video-taped lessons, Problem solving scale, Flanders, TONI-3
3.3 Curriculum factors	Interviews, video-taped lessons, documents, AET

Procedure

The data for this case study were collected from November to May of the 1999-2000 school year. The researcher visited the classroom at least once a week during the time period.

Qualitative data collection and analysis. The qualitative data were gathered through interviews with the students, teachers, and parents of the students, as well as through the video-taping of lessons, and curriculum document analysis. These data were collected for seven months during the school year. The multiple sources of information and collection methods provided a means to triangulate the data. "Especially in terms of using multiple methods of data collection and analysis, triangulation strengthens reliability as well as internal validity" (Merriam, 1998, p. 207).

Audiotapes of the interviews were transcribed and analyzed using an emerging themes and categories approach (Miles & Huberman, 1994). The videotaped lessons were analyzed for (a) evidence of problem solving strategies and the occurrence of problem solving and transfer within the classroom and (b) level of teacher-student interactions using the FIAC-M. The relevant documents, as well as the interviews and videotaped lessons were examined for evidence of instructional strategies and activities related to problem solving.

Quantitative data collection and analysis. The researcher administered the TONI-3 to all the students at the beginning of the study. In order to assure appropriate administration of the test, prior to the administration the researcher (a) consulted with one of the authors of the test, and (b) practiced giving the test.

The TONI-3 test booklets were scored and an intelligence score derived for each of the students in the study.

The Problem Solving and Thinking Processes scale was given to the students and the two teachers at the beginning of the study. The paper and pencil instrument was group-administered and required no special training for the examiner. This five-point Likert-type scale was scored, with a total score, and three sub-scale scores derived for each student and teacher. According to the Scale, the higher the score, the stronger the individual's self-efficacy for problem solving.

All of the lessons were analyzed according to Bloom's cognitive taxonomy. Initially, the researcher and classroom teacher completed the categorizing by independently reviewing the lesson transcriptions. While watching the video and using the transcription as a guide, every question and response of students and teachers were coded according to Bloom's taxonomy. Differences were discussed with the researcher's major professor, and an agreement reached on the appropriate category. The academic engaged time data, collected according to the Engagement Check protocol, was conducted every 15 seconds for 15 minutes totaling 60 observations per session.

Trustworthiness

According to Drew, Hardman, and Hart (1996), "In order to maximize the trustworthiness of qualitative findings, it is essential that the investigator cross-check information with multiple sources. These multiple sources might include other informants or they might involve official documents or other written records. To ensure trustworthiness of this case study, the researcher used a number of methods and collected a variety of data in order to provide "...a foundation of description--of context, site, actors, and action" (Behrens & Smith, 1996, p. 979). Merriam defined internal validity as:

> The extent to which research findings are congruent with reality-is addressed by using triangulation, checking interpretations with individuals interviewed or observed, staying on-site over a period of time, asking peers to comment on emerging findings, involving participants in all phases of the research, and clarifying researcher biases and assumptions (Merriam, 2001, p. 218).

To strengthen the internal validity, the researcher spent approximately 60 hours videotaping and observing in the classroom over a seven-month period. Considerable time was spent testing the students, interviewing key participants, and examining relevant documents. Peers, primarily the lead teacher in the classroom and the researcher's major professor on the study, provided valuable assistance in analyzing the lesson and interview data. The lead teacher, independent from the researcher, read and analyzed all the videotape transcriptions of the classroom lessons. Over the period of a month, she and the researcher met five times, discussed the data and reached agreement on the analysis. While developing the emerging categories of data analysis, the researcher met routinely with her major professor, and together they analyzed key pieces of data. The researcher and classroom teacher independently completed the categorizing. Differences were discussed with the researcher's major professor, and an agreement reached on the appropriate category.

In order to ensure verification of the qualitative findings, there were varied and multiple data sources (i.e., teachers, students, parents), collection methods (i.e., interviews, classroom lessons, document examination), and data types (i.e., audio recording, videotaping). Taken together, the varied sources of information provided a comprehensive picture of the classroom activities.

To enhance reliability on the quantitative measures, the researcher trained on the administration of the TONI-3 and the engaged time procedure. Prior to the beginning of the data collection, the researcher administered one TONI-3 for training purposes and practiced the Engagement Check, the group engagement observational procedure in the classroom. To insure inter-rater reliability on the Engagement Check, the researcher and a colleague conducted practice observations and reached 85% agreement.

An audit trail was established for the collection of all the qualitative data so that the process can be retraced. Miles and Huberman (1994) recommended logging and describing procedures " . . . clearly enough so that others can understand them, reconstruct them, and subject them to scrutiny" (p. 281).

The researcher continuously reflected on the study recognizing inherent biases and perspectives regarding the study and the model being examined. Throughout the analysis, the researcher met with the lead teacher and her major professor to analyze the findings and conclusions. These discussions encouraged the researcher to resist imposing her views and biases on the findings. An audit trail was kept cataloging the transcriptions from the audiotaped interviews and the videotaped lessons, the documents, as well as the records of quantitative data.

CHAPTER FOUR

Results

The purpose of this study was to examine the use of problem solving strategies and instruction within the Montessori model of learning and to determine if problem solving and transfer occurred. The data were collected over a seven month period in a fourth through sixth grade classroom in a Montessori school. Participating in the study were sixteen students, two teachers, and sixteen parents. The primary data sources were 24 videotaped lessons in the classroom (see Table 2) and audiotaped interviews with all the participants. The lesson and interview transcriptions were used for the content analysis. Data collected from relevant documents, TONI-3 and Problem Solving and Thinking Processes scores, FIAC-M teacher-student interactions, and academic engaged time in the classroom provided additional information.

With regard to the videotaped lessons, 11 (46%) of these were small group lessons with a teacher and six or fewer students. Lesson P was a student led class meeting without teacher input. The remaining 12 (50%) lessons and Lesson P had an estimated number of 14 to 18 students and one teacher. The subject matter ranged from teacher-directed math, science, history and reading lessons to a student-directed class meeting and science experiment.

The exact number of students in Lessons N, S, H, U, I, J, Z, B, AA, P D, X, and C was not known because the video camera was stationary and did not always show every student in the lesson. Consequently, at times when the students' verbal communications in the lessons were analyzed, it was not

Table 2

Classroom Lessons

Lesson	Date	Minutes	Teacher	Grade Level	# of Students	Subject/Topic
N	11-17-99	55	Lead	5	15*	History–Human migration
L	11-18-99	59	Lead	4	6	Pre-history–Permian era
S	11-19-99	20**	Lead	4-6	18*	Class meeting
O	12-03-99	50	Lead	4	6	Pre-history-Triassic, Mesozoic periods
G	12-07-99	45**	Lead	5-6	4	Geography-convection currents experiment
H	12-09-99	42	Lead	5	15*	History–Ancient China
W	12-09-99	39**	Lead	4	5	Pre-history–Jurassic period
E	01-10-00	18	Lead	5	1	Math–decimal multiplication
R	01-14-00	10**	Lead	4	5	Pre-history–Tertiary period
U	01-18-00	40**	Lead	4	15*	Math–word problems
F	01-25-00	20	Lead	6	2	Math–squaring trinomials
I	01-25-00	62	Lead	5	15*	History–Ancient China
V	01-25-00	13	Lead	5	2	Math-fraction multiplication
J	02-02-00	39	Lead	5	15*	History–Ancient China
A	02-04-00	35	Lead	4-6	5	Individual assistance
Z	02-19-00	15**	Lead	4-6	18*	Class meeting
B	04-26-00	39	Assistant	5	15*	Reading-novel study
AA	05-03-00	34	Assistant	5	14*	Reading-novel study
M	05-06-00	20**	Lead	6	5	Reading-novel study
P	05-06-00	28		4-6	18*	Class meeting–student led
D	05-10-00	45	Lead	4	15*	Math–algebra word problems
X	05-14-00	48	Lead	4-6	15*	Independent study presentations
C	05-15-00	13	Lead	4	15*	Science/Writing–animal research/transition sentences
Y	05-16-00	29**	Lead	6	4	Geometry – volume of sphere

(*) - Estimated number of students (**) - Partial Lesson Videotape possible to identify the student speaking. In the analysis, these student comments were coded as *unknown student.* Also, at times during the videotaping of lessons there were (a) one or more of the four students in the classroom who were not in the study, and (b) students from the other fourth through sixth grade level classroom participating in the lesson. Students who fell into either of these two categories were coded as *nonparticipating student*. The unknown students and the nonparticipating students were excluded from the data analysis. However, these students' verbalizations will appear occasionally in the following excerpts from the transcriptions when they were integral to the interactions.

The average length of the videotaped lessons was 34 minutes with the shortest being 13 minutes for Lesson V and the longest being Lesson I at 62 minutes. In 67% of the lessons, the entire lesson was recorded with the video camera. In eight of the 24 lessons (33%), only a portion of the lesson was recorded (see Table 2). Using these data, each of the research questions was systematically addressed. The rest of this chapter is devoted to the results.

1. What Montessori model characteristics are similar to those characteristics reported in the problem solving research that facilitate transfer?

According to researchers, certain instructional strategies encourage transfer and have a positive effect on the quality of the process. The variety of the learning opportunities, the quality of the learning, the depth of the learning, and metacognitive awareness are four key strategies.

Variety of experiences is referred to as "multiple knowledge representations" (Brenner et al. 1997), which means presenting the information from a variety of perspectives and applications. Also, multiple problems that are similar in strategy encourage decontextualization of the learning and generalization of the solution. Resnick (1977) recommended the development and explanation of problems and solutions as an instructional emphasis.

In the problem solving research, quality refers to how meaningful the learning is for the learner (Brooks & Dansereau, 1987; Mayer, 1987). Incorporating instructional methods such as discovery learning, concrete manipulatives, and connecting old and new knowledge encourage meaningful learning (Mayer & Wittrock, 1996). Problems that have real world applications and are generated by students are particularly powerful (Eggan & Kauchak, 1999).

The more time spent learning to solve problems (Glick & Holyoak, 1987) and the more opportunities learners have to practice (Cormier,1987), the greater the understanding and the more likely problem-solving will transfer. Brophy (1992) discussed the importance of depth of understanding versus the acquisition of content knowledge. Opportunities for discussion and sharing of ideas facilitate transfer (Vanderstoep & Siefert, 1994).

Skilled problem solvers are metacognitively aware of their thinking processes (Masui & DeCorte, 1999; Mayer & Wittrock, 1996). Strategies such as reflecting on what is happening during the learning and problem solving (Masaui & DeCorte, 1999), making decisions about use of time and effort (Halpern, 1998), and possessing a positive disposition (Dweck & Elliott, 1983) contribute to the quality of transfer.

In examining the lesson and interview transcriptions as well as the classroom documents, variety of learning experiences, quality of learning, depth of learning, and metacognitive awareness were all evident to some degree.

Variety of Learning Experiences

There were a variety of learning experiences in six of the 24 (25%) lessons. For example, during a three-lesson sequence the fifth grade level students had varied experiences in designing and implementing a history fair. This project (Lesson H, I, and J) began with an introductory lesson on ancient China (Lesson H). Prior to this lesson, the students had chosen, by voting, an ancient civilization to study and had selected China. In Lesson H the teacher presented background information on early civilizations and provided an introduction of the Chinese dynasties. In lesson I, after the students had completed their individual research on specific dynasties, they discussed the information they had learned and brainstormed ways to present their information to an audience. The students agreed on a fair as the product of their study. They made maps and sketches of costumes prior to their next history lesson. During lesson J the students decided on committees needed for putting on the ancient China fair and signed up for responsibilities. The project culminated in the presentation of an ancient China fair that was held for students, parents, and teachers.

Another example was in Lesson AA, when the assistant teacher and fifth level students were discussing a novel, *Summer of the Monkeys*. The teacher was helping the students explore different perspectives of the characters:

> *Teacher*: We already talked about the fact that Jimbo is an antagonist as someone working against J. I want to talk a little differently about these players. I want you to think for a minute about how these characters, and J's interaction with them, will affect these goals of catching the monkeys. What kind of influence are they on J and how do they affect J and his ability or his working out of catching the monkeys? I just want you to think about it for a minute. We are going to go around and talk about that. We are going to give them a plus or a minus or perhaps you will want to give them both a plus or minus if you feel like they are both a positive and negative influence. Think about if each character is a

> positive influence on J as he tries to reach that goal or if they are a negative influence. And, I really want you to think of why you say that, what in the novel has caused you to say that (Lesson AA, p. 3).

Using these guidelines as the framework for the lesson, the students discussed characteristics of the characters. This provided the students with an opportunity to discuss the characters from a variety of perspectives and to listen to one another's opinions.

In the interviews there were several instances where students' and parents' comments reflected the opportunities students had to learn information in various ways. A parent of a sixth level student had the following to say:

> They can pick any subject, research it, but that is not the end. With the most recent independent study that [Student 3] did on Squanto. He not only researched it, he presented it before a classroom, which is public speaking. They are taught to take questions from the audience, which is impressive to me. It's on the spot--you know, thinking on your feet. And then they do it in costume, which again is the creative corners of their brain. I don't know of any other education setting where it is so encompassing -- where they just really touch every area (Parent of Student 3, Interview, p. 3).

Another example is Student 3's comment on extending a math work:

> Like three digit numbers--explaining 652 times 242 and we just laid it out in expanded notation and put it on the paper roll and graphed it out and then we just do it on paper (Student 3, Interview, p. 2).

Quality of Learning

The content and instructional strategies of many of the lessons reflected at least one quality of learning characteristic. Eleven of the lessons (P, S, V, B, H, I, J, G, X, N and E) were particularly representative. For example, Lesson G was an experiment on convection currents. The teacher explained that the experiment was preceded by a series of lessons on the layers of the earth and plate tectonics.

This experiment was in preparation for the next lesson that was going to be on oceans and ocean currents. The experiment was conducted by the students, without teacher supervision or intervention. In describing the process, the students used a research guide form that is used for all experiments. On the form the students described the experiment, the materials needed and the steps and procedures. The lead teacher described the rest of the process:

> Then there is a place where they stop and make a prediction of what they think is going to happen or an hypothesis, what they foresee happening in the experiment. And then at that point, after they have hypothesized and talked about that as a group, they may have one or two within the group of different predictions, they get that recorded and then they go ahead and perform the experiment (Lead Teacher, Interview 4, p. 2).

Lesson G was an example of discovery learning. The students were testing their hypotheses and generating connections. They were actively involved in questioning and applying their knowledge to understand the experimental process.

Connecting old and new knowledge is an important part of the Montessori curriculum.

> One of the basic tenants . . . is the interconnectedness of all things. That is why in the curriculum you do not do just science or geography or history. You do those things but they are all bound together and called the cultural subjects…you don't learn anything in isolation. It all has a purpose . . . it all has a place where it fits into a bigger scheme and bigger picture (Lead Teacher, Interview 4, pp. 19-20).

In Lesson B the fifth grade level students were engaged in a discussion with the assistant teacher about the book they were reading. The goal of the lesson was for the students to understand the concepts of protagonist and antagonist. The students and assistant teacher are sitting in a circle. The teacher began the lesson using attribute blocks and with rope fashions a Venn diagram on the carpet in front of the students.

> *Assistant Teacher*: Here's an example of a transfer. Remember the attribute blocks? (Student 11), do you know where those attribute blocks are? Why don't you get a few and let's talk about that for a minute because that will be a good thing for you to relate to help you understand where I'm going with the lesson today. Go ahead and put your books on the floor. You do not need your work plan right now. Do you remember what you did with the attribute box? Can someone come up very quickly and do something with the attibute blocks. Let's think about what this circle will be and let's think of what this one will be. (Lesson B, p. 1).

Following a discussion on previous activities with a Venn diagram, the assistant teacher says:

> *Assistant Teacher*: Okay, now we are going to do something with your novel that is kind of like this. Only we are going to do it with characters in the story and I want to talk to you a little about it but first we are going to give some terms to the characters just to introduce them to you a little bit. Have you ever heard of the protagonist? (Lesson B, p. 2)

According to the lead teacher, one of the major topics in the Montessori biology curriculum for grade levels 4-6 is the Timeline of Life. This topic is first introduced to the students at the first through third grade level. The content for these higher levels continues the emphasis on the interrelatedness of life. The focus is on the development of plants and animals. The lead teacher shared the following description of how a student connected previous knowledge with new knowledge and how the biology timeline information was meaningful for her.

> We were studying the time line with the fourth graders, and we were talking about the plants and animals . . . so they were talking about how the plants go back into the earth and fertilize the soil, and then more plants are able to grow, and then the animals are able to use them . . . and one of them said, 'Hey, wait a minute, that is just like the circle of life. That is what they mean by the circle of life, now I understand.'
>
> We have charts in lower elementary that show circles of life, you know the nitrogen cycle or the water cycle, and she was connecting that that was circular in pattern and cycle. And when we got to simultaneous study of the ocean, we were talking about the water cycle, she said, 'That is another one of the circles, another one of the cycles.' So she began connecting that way (Lead Teacher, Interview 2, page 9).

Depth of Understanding

This classroom afforded opportunities for in-depth learning. One parent stated, "They learn things so well that they don't forget them. I mean they are ingrained in them. They don't learn things to pass a test. They learn things, and this knowledge they will have forever."

The ancient China lessons (H, I, and J), spanned a two month time period. The lessons culminated a month later in the students operating an ancient China fair for students, teachers, and parents. In these lessons the fifth level students brainstormed about the vehicle for presenting their research information and about the strategies for designing, organizing and producing the fair. The teacher would offer suggestions and guide the students, but the decisions were ultimately made by the students voting.

In the interviews students and parents provided comments related to the depth of learning. For example, the following student said he had been working on this particular research "since January," and the interview was conducted on Feburary 29th.

> *Student 10*: We are doing research about the ocean, and I guess that is pretty fun. . . . We are also doing independent study projects, all of us, and I'm doing dummies. We are researching that but everybody has their own independent study thing.
> *Researcher*: How long have you been working on that?
> *4th level student*: Since January. . . . It's pretty fun. My last independent study was on ospreys, they are a type of bird of prey (Student 14, Interview, p. 2).

Parents had the following to say when asked, "How would you describe Montessori education?"

> Well, the first word that comes to mind is just hands-on and learning to think independently. So much of the work is designed so that the child pretty much has to think through conceptually what they are doing rather just memorizing something or learning something just again kind of on a

> superficial level. This way they have a deeper understanding. Probably the overall term that always comes to mind is just the hands-on experience where you are working through it yourself to learn and to understand (Parent of Student 16, Interview, p. 1).
>
> Last year when they were studying all of the plants out in the desert area, we would drive and he would identify them. He would identify the plants and he would tell me how often they bloom, or he would say, 'That one is in bloom and it doesn't bloom but once every four years; so, look at it this year because it's going to be four more years.' And he knew so much more. . . . And I think that [Student 3] today could still drive down that street, identifying that plant, and tell you facts about it (Parent of Student 3 , Interview, pp. 6-7).

These parents' comments illustrate their belief that the Montessori curriculum provides the students with in-depth learning opportunities.

Metacognitive Awareness

In the lessons, numerous examples of teachers and students illustrating metacognitive skills were present. Planning their work is a key part of the learning process. The lead teacher remembered a sixth grade level student sharing with the fourth grade level students about scheduling the week's work. "Well, I learned if I plan as much as I can on Monday and nothing on Friday, I can use Friday as a catch up day" (Lead Teacher, Interview 2, p. 4). The lead teacher continued with:

> They have all kinds of different strategies that they use and share and we do a lot of talking about that because it is not completely natural for fourth, fifth, and sixth graders to plan work for a week. Although by the end of the year generally they do it very successfully and can follow the work plan (Lead Teacher, Interview 2, pp. 4-5).

In three lessons (E, V, and F), students verbally displayed positive dispositions toward learning. For example, in Lesson E, Student 11 commented, "It isn't awfully hard." following the lead teacher's exclamation of "Wow!" to the student's completed work (p. 5). In Lesson V, Student 11 expressed confidence and perseverance in completing math tasks.

> *Teacher*: See how to do these?
> *Student* 11: It's really not hard.
> *Teacher*: No, it really is not that hard. Why don't you guys finish up this card? You can work on it together and go ahead and do drill card 3…
> *Student 11*: Do we have to do another card and another drill since we did this?
> *Teacher*: Maybe you could do it tomorrow or Friday?
> *Student 11*: Okay. Could we do it right now?
> *Teacher*: If you want to. Keep going, sure (Lesson V, p. 3).

In Lesson F the teacher was presenting new information to two sixth grade level students on squaring trinomials. Toward the end of the lesson, the teacher said, "Now we are ready to put it all together, right? Good luck." Student 3 responded, "It's not going to be that hard. " The teacher continued to give them instructions and then asked, "You know how to check it, right?" and Student 3 answered, "Okay, I think I got it" (Lesson F, p. 4).

In Lesson C, fourth grade level students were learning about writing transition sentences. The students have gathered information on an animal based on questions generated during a previous lesson. The students were to eventually write a two-paragraph research. The teacher led the students through thinking about a logical way to sort information into two categories. She was teaching the concept "linking sentence," making transitions using what is known to get to the next paragraph.

> *Teacher*: If you wrote the first paragraph about science, like the anatomy of dogs, the very last sentence could be one that ties the first and second paragraph together. Sort of like you took a piece of string and tied it together--to show that they really do belong together. You are not just creating and writing about two totally different things.
>
> You could say all dogs have these vital functions and my dog, the beagle, has them as well. Then the next paragraph could be about my very own dog. And it would be tied together. Do you see how that last sentence talks about the first paragraph, and it talks about what's coming up next? We call that . . . does anyone know what we call a sentence like that? Any ideas?

> *Student 7*: A tying sentence
> *Teacher*: A tying sentence or a linking sentence. But the name they give it in writing is transition. See how it is a little bit of a transition. Trans means to go from one thing to the next--like what other word has the prefix trans?
> *Unknown Student*: Transportation
> *Teacher*: Transportation, which means what? Go from one place to the next. So transition means a sentence that takes you from one place to the next. So if you have two paragraphs, the transition sentence comes at the end of the first paragraph and it talks about whatever was in the first paragraph and it tells you what's coming up in the second paragraph. They are helpful so that you know what your two paragraphs are talking about.
> Okay, so let's think about this. Think about the research information that you have about your animal. Do you think you could group the information into two different groups one for each paragraph? Think about it--do you have two kinds of things that you could write about? (Lesson C, p. 4)

In this part of the lesson the teacher used concept development to lead the students to think about a logical way to sort information into two categories. The lesson continued with the teacher and students deciding that one paragraph would be about the systems and the other about characteristics of the animal. Working definitions for systems and characteristics were established. The teacher then guided the students into categorizing their questions into one of the two paragraph headings.

> *Teacher*: Let's see [Student 7], read yours. What do you have?
> *Student 7*: How is it useful or harmful to you or other animals?
> *Teacher*: It is not a system so I'd say it's a characteristic. I've got one. In which ecological region is it found?
> *Group Response*: Characteristic.
> *Teacher*: Didn't we talk about habitat and what else? Didn't we have geography--where it lives--that is what that is. I think we had one that lived in the rain forest. We had one in a continent in another habitat. This would be more like where. Okay, [Student 6] what about yours? I have, how does it protect itself.
> *Student 6*: It's like defense and a characteristic.
> *Teacher*: It could have sensed danger and then the messages could be sent to its brain--kind of like a nervous system. I'm going to call that a system. I have one, what does it eat?

> *Student 6*: Characteristic. I have one too. How does it protect itself? Some of them are like a characteristic so could we put it in both? Some look scary and have all these horns on it.
> *Teacher*: That would be more like a characteristic. That could go either place.
> *Student 6*: In which bio-geographic region is it found?
> *Teacher*: That's going to be like the continent. I think that ecological and habitat are sort of the same (Lesson C, p. 5).

By using inductive inquiry the teacher is helping the students understand the concepts and to think about the process of categorizing information in a logical, mindful way.

In the following, the lead teacher described a sixth level student's reflective learning:

> He was working on square roots and different things and he sat down for his next lesson and he said, 'Okay, I've been thinking. Well we keep working with square roots, if you can find the square root of something, does that mean you can find the cube root of something?' And I said, 'Well, tell me about that, why do you think we ought to be able to do that?' He said, 'Well, I noticed something in the square, that the root is really just the base of it and a number squared is just a number times itself twice. So if you can cube a number and multiply times itself three times, can you then find the cube root of a number?' I said, 'You are exactly right.' And then he said, "Well then could you find a fourth root?'…. I said, 'The fourth dimension is time.' He said, 'It's something in the dimension of time like measuring it and then measuring the same thing again at a later period like an hour later.' And I said, 'Yes, that's a start to what it is.' And he said, 'I can sort of figure that cause you can have a tenth root or a twentieth root.' And I said, 'Well, you really can, you just can't do it - you can sort of imagine it but you can't --it's a very abstract concept.' He said, 'Yes, I think so--scientists are really sort of researching about math.' And he said, 'Most people think of math as being limited, but it's really unlimited. It's really not as limited as it seems' (Lead Teacher, Interview 3, pp. 3-4).

This is an example of a student being metacognitively engaged. According to the teacher's description, he was thinking about the mathematics concepts in a thoughtful way and was making a conscious attempt to think about the subject.

Lesson R was on the Tertiary period. During the lesson, the teacher facilitated a discussion with the fourth grade level students on the information they had gathered from research prior to the lessons. Only part of the lesson was taped, but the teacher explained to the researcher that at the end of the lesson the students were asked to use their research information to construct hypotheses for causes of the supposed mass extinction. The following excerpt from the lesson illustrates the teacher encouraging the students to be thoughtful.

> *Teacher*: Here's what we're going to do. We already know what happened in Crustacean. Today we're going to talk about what happens in Tertiary. As we talk about the things that are different here, after the mass extinction and before, I want you to be thinking in your mind, not saying it out loud but thinking it, what kinds of things might have happened to cause all of those animals to go extinct. Scientists don't know for sure why the dinosaurs went extinct. They have some theories. But I want you to come up with your theories. You don't have to come up with it today, just be thinking about it. Why this happened based on the facts we have shared about what started happening around this time. I'm going to ask you later. Keep in mind how that fact might have affected what might have happened.
>
> Let's look at our facts today and see if we can come up with the riddle of why all of those animals go extinct. So you be thinking about that. Let's start by looking at our time line. (Lesson R, p. 1).

The teacher is directing the students to be thoughtful. In this brief introduction to the lesson, the teacher tells the students four different times to *think* about what caused the extinction. She is encouraging them to work toward the goal of coming up with their own theory.

In summary, the Montessori model of learning, as demonstrated in this classroom, has characteristics similar to those characteristics reported in the problem solving research. Specifically the four instructional strategies of variety of the learning opportunities, the quality of the learning, the depth of the learning, and metacognitive awareness were evident in the videotaped lessons, the interviews, and the relevant documents such as the written Montessori curriculum.

2. In what ways does problem solving within the Montessori classroom transfer?

In answering this question, problems were initially defined and categorized. Using the definition, "Problem solving is a *cognitive process* which is aimed at achieving a *goal* when no *solution* is apparent to the problem solver" (see p. 23), each lesson was initially examined to determine if a problem was present. To be a problem, the example had to have three parts (e.g., a goal, a process, and a solution) and had to be solved by the student (e.g., the problem solver).

Problems were also categorized according to the missing part as defined by Maker (1992). For example, problems in which the problem and process are known to the teacher and students but only the solution is known to the teacher, are categorized as Type I problems. Type II problems are those in which the problem, method, and solution are known to the teacher, but the method and solution are not known to the student. Problems, which are known to the teacher and student, but several methods and solutions (a range) are possible is a Type III. Problem Type IV situations have methods and solutions that are both unknown to the teacher and the student. A problem is categorized as a Type V if all three (problem, method, and solution) are not known to the teacher and student.

Following the identification of problems, the 24 lessons were examined for evidence of problem solving strategies and the occurrence of problem solving and transfer. The transcriptions from the videotaped lessons were read and analyzed by the researcher and the lead classroom teacher. In addition, the researcher's major professor helped define and clarify the categories.

Interviews were conducted with the students, teachers and one parent of each of the students. These interviews were audiotaped and transcribed. Each interview was analyzed for themes and categories. Again, the lead classroom teacher and the researcher's major professor assisted with the classification of the information.

Nineteen instances of problem solving, three instances of problem solving transfer and 25 instances of knowledge transfer were identified from the content analysis of the verbal responses in each of the 24 lessons (see Table 3). Other instances were identified from interviews with the students, teachers, and parents. Fourteen instances of problem solving, 11 instances of problem solving transfer and 47 instances of knowledge transfer were described in the interviews (See Table 4).

Table 3

Problem Solving and Transfer in the Lessons

Lesson	Problem Solving Instances	Problem Solving Transfer Instances	Knowledge Transfer Instances
N			5
L			1
O			4
G			2
H			1
W			2
E			2
F	2	2	
I	5		2
J	7	1	3
M			2
P	5		
Y			1

Using these criteria (the problem met the definition, the student was the solver and a part was missing), ten of the 24 lessons (42%) had problems (see Table 5). Of these 10, 60% of the lessons had Type I problems, 20% had Type II problems, and 30% had Type III problems.

One of the ten, Lesson G, was a geography experiment on convection currents. For the method, the students followed the steps listed on the standard research form that is used in the classroom for all experiments. This is a Type I problem because the only unknown to the students was the solution. The lead teacher described problem solving as it occurred in Lesson G:

> Well, this particular group ran into a problem, and it was that the first time they tried it, it didn't work. And the mulch, what's supposed to happen is that in the pot of boiling water, once it starts to boil, then you have all the bubbles rising to the top and the mulch is supposed to take the food coloring, and it would make a ring of color; you would be able to see it rising to the top, falling, rising to the top and then falling like a convection current. And that didn't happen the first time. So, they had to stop, and a teacher does come in that point and then ask, 'What's going on? What do you need to do?' That is when they have to reevaluate and decide; okay, we used too much water, let's try it with less water. They have to figure out what to do next, and then they try it again with less water and it does work. So working through that I thought was an interesting point (Lead Teacher, Interview 4, pp. 4-5).

In Lesson G the students were following the research form and when the known method was not working, the teacher guided them through the process for a second time. Therefore, this is an example of a Type I problem.

Five lessons were on mathematics (Lessons E, U, V, D, and Y) and had Type I problems. The content of these lessons focused on teaching the students specific mathematics skills such as (a) how to do decimal multiplication or (b) how to solve word problems using algebra. Although the students did not know the method, the teacher was very deliberate in teaching the methodology (procedure) as she directed the students toward solving the problem. The students reached the solution, but only through the supervision and the guidance of the teacher. Therefore, since the teacher directed the students step-by-step to reach the solution or "get the right answer," these lessons were considered to be Type I. The only math lesson that included more than a Type I problem was Lesson F.

Four of the ten lessons had Type II or III problems. The lesson problems related to: (a) trinomials in mathematics (Lesson F), (b) presenting research information to the class (Lesson I), (c) developing and organizing committees for the presentation (Lesson J), and (d) classroom supplies and responsibilities (Lesson P). The teacher stated the problem in three of the four lessons. The lessons' problem types are described below.

Lesson F. The goal of this lesson was to teach two 6^{th} level students how to square trinomials. This is a Type I problem because the teacher used the students' knowledge of squaring binomials to guide them in learning how to square trinomials.

The lesson began with the following interaction between the lead teacher and two 6^{th} level students:

> *Teacher*: Okay, now trinomials. So (to Student 3), can you tell me what the difference is going to be?
> *Student 3*: In what part?
> *Teacher*: Instead of having 22 times 32 what might we have?
> *Student 3*: 122X132
> *Teacher*: Right, we are going to be multiplying a trinomial which must have three parts. So let's do –why don't you put the heading on the paper and call it graphing trinomials? We are not going to seven today, just a sample. Go ahead and write that down. You have to write on the left edge of the paper so you can imagine we are going to have three parts for each one. So, (Student 9), what is the first thing that we do?

Table 4

Interview Descriptions of Problem Solving and Transfer

Student	Knowledge Transfer	Problem Solving	Problem Solving Transfer
1	S		T
2	S	T	
3	SSSTPPP	TTT	TTTT
4			
5	SS	T	
6	SPP	P	
7	TTP		
8	SS	P	
9	SSTP	T	TT
10	SSSP		
11	SSTTPPP	S	
12	SSP	PP	P
13	P	P	P
14	SST		
15	SSPP	P	P
16	SP	T	T

S = one student instance as described by the student
T = one student instance as described by the teacher
P = one student instance as described by the parent

Student 9: Write an expanded notation.
Teacher "And how do we write an expanded notation?
Student 9: 200+30+5 X 100+126.
Teacher: Right, so you have that. You can already see that it's going to be longer, right? So, now instead of just multiplying this times this number and this times another number, we must do it three times. We are going to take 200 plus 30 plus 5 times 100; then 200 plus 30 plus 5 times 20; and then 200 plus 30 plus 5 times 6. So think for a second, can you picture in your mind what the graph is going to look like? The graph for binomials has 100s then two sets of 10s then it had units.
Student 3: Will it have 1000s?
Teacher: It will have 1000s.
Student 3: Will it have 1000s,100s,10s then units?
Teacher: It might, let's try it and see (Lesson F, p. 1).

Table 5

Problem Types in Lessons

Lesson	Lesson Topics	Number of Problems in Lessons	Problem Types
G	Geography-convection currents experiment	1	I
E	Math-decimal multiplication	1	I
U	Math-word problems	1	I
F	Math-squaring trinomials	3	I, II, II
I	History-Ancient China	1	III
V	Math-fraction multiplication	1	I
J	History-Ancient China	1	III
P	Class meeting-student led	2	III, III
D	Math-algebra word problems	2	I, I
Y	Geometry-volume of sphere	1	II

This excerpt from Lesson F illustrates how the teacher provided the goal as well as the method for the students. This was a Type I problem situation because the only unknown for the students was the solution. The teacher continued the lesson by leading the two students through the steps using questioning such as: "Okay, (Student 9), what is the next step?"

The lesson was extended to include the squaring of pentinomials and quadrinomials. The squaring of the pentinomials and the quadrinomials are Type II problems because the method for solving the problems was not already known to the students. The teacher did not walk the students through the steps like she had done for the process of squaring trinomials. To extend the lesson she said, "When you have your work done you can try a pentinomial. What would a pentinomial be?" (Lesson F, p. 3). After more discussion, the teacher asked the two students, "Let's do some predicting. Let's imagine we have a quadrinomial. What would our graph look like? What would go here?" (Lesson F, p. 4).

Three problems were present in Lesson F. The first problem is a Type I because the two 6th level students were guided through the process for squaring trinomials. Their prior knowledge of squaring binomials was used by the teacher as a model. The other two are Type II problems because the teacher did not guide the students through the method. The process as well as the solution was unknown to the students.

Lesson I. In this lesson, the teacher said, "What ideas do you have about presenting our ancient China information?" (Lesson I, p. 1). The students knew the goal (i. e., the students are to make a presentation) but not the process or the solution (i.e., a Type III problem). The teacher, on the other hand, knew the goal and the possible range of processes and solutions. In discussing the process in an interview, the teacher shared the following:

> They had gathered their information already so when we came together, I just presented the problem--we have our information, now we have to present it somehow. What are we going to do and how are we going to do it? They brainstormed then what ideas they had for presentation and at that point, I didn't have an idea selected as one better than another, and we really didn't spend, at that point, a lot of time discussing the options. We just listed all of the options. Then once they got those listed, really most of it is just talking, besides me sort of trying to help them not all talk at once basically. And letting them talk through the ideas. 'Okay, someone said computer program, tell us more about that--what do you mean by that?' Trying to let them hear each other and listening to them and their different ideas. I think I guided them at that point to narrow it down to five. So after we had discussed and heard each other's ideas, then I guided them to narrow it down to five and then we took a vote (Lead Teacher, Interview 4, pp. 17-18).

This illustrates the characteristics of a Type III problem situation. While the teacher and students knew the goal, the method, and solution were unknown. Although there were parameters for the process that were known to the teacher, the students brainstormed the possibilities and reached a solution for how they would present the information.

Lesson J. One week following Lesson I, the teacher presented Lesson J, the third history lesson on their ancient China research, to the fifth grade level students. During the previous lesson (Lesson I), the students had agreed on a fair as the product of their study and had begun to discuss some possible committees that would be needed. The lesson began with the teacher and students discussing general plans for how they will share their information during the fair. After several minutes of discussion, the teacher said,

> The other thing that we talked about last week that we need to talk about today is having some different committees for different things, and I want you to think a little bit about this. I wrote down things we talked about last time, one was a food committee and their responsibilities would be what? (Lesson J, pp. 4-5)

The main objective of Lesson J was for the students to decide on committees needed for the fair, for the students to sign up for the committees and to begin discussing the logistics of the presentation. A parent offered this account of her daughter's experience with making decisions in the classroom.

> She told me that they were doing a project, and they were doing it together and somebody couldn't get something done or whatever, so they all got together as a group and figured out what they needed to do, and they split up and all got it done. . . . I was really impressed with how they worked together (Parent of Student 8, Interview, pp. 2-3).

Lesson J was a Type III problem situation because the planning of the fair, for the most part, was left up to the students; however, the teacher did share some guidelines and ideas.

Lesson P. The fourth lesson, Lesson P, was a class meeting of approximately 18 students in grade levels four through six. In the following interview the lead teacher described the format for discussing problems in class meetings.

> They discuss any problems that need to be brought before the class, and they learn how to determine what is a class problem and what is an individual problem. And what is a problem that needs to be discussed just with the girls or just with the people who play basketball. Then they hold smaller meetings with those things. [*The students have*] all of their rules they have come up with during the problem discussion time that needed to be worked out and solved.
>
> But generally it runs pretty well, and they discuss problems. They take the problem and then they take ideas for solutions. They usually take a vote and the leader then restates the solution, and they vote on them and then they state the solution so everyone is clear on it, and the next week they work on another and some get solved and never come up again (Lead Teacher, Interview 3, pp. 8-9).

Although the teacher was present in the room during the class meeting in Lesson P, she was not sitting with the students on the carpet, and she was not a part of the discussion. The student leader facilitated the class discussion, which included student acknowledgements and sharing, a discussion of current events, and a discussion and solving of two class problems. Students, not the teacher, stated both of these problems. The first problem was that students were returning pencils not sharpened to the supply shelf. The second problem was that there were not enough erasers on the supply shelf. Both problems were Type III problem situations because the class leader could choose the method for solving the problem and there was a range of possible solutions. Another description of the class meeting process for problem solving was shared by a parent:

> She talks about how they are problem solving. . . . This last week the kids were talking in class meeting about the problem of so much talking going on in class. Some of the fourth graders were trying to come up with solutions for this problem. During class meeting the teacher pretty much lets the students discuss solutions and the teacher stays out of it (Parent of Student 6, Interview, p. 2).

The lead teacher provided the following examples of how the students used the process of solving problems through a class meeting.

> Another time they used their prior experiences in something new is their class meeting format that they have had since first grade. . . . A couple weeks before the trip, something had come up in the classroom. I can't remember what it was. It was at the end of the day and it was about ten children that were involved and they had some problem or some concern, and they said, ‘What are we going to do about this?’ And I said, ‘Why don't you have a meeting?’
>
> And they went over by themselves and had a meeting just like a class meeting. They elected someone to be the leader for that time. And that person facilitated the meeting . . . and they were able to share and remembered the format of sharing all the possible solution and discussing the solutions and then they voted on a solution.
>
> Then they decided to implement that solution and they went through all of that process, and then I came back and checked with the leader, and the leader shared what the solution they came up with was and they had done it themselves. So they do use that--they will slip into that format even though it is not an official time, they just know how to run a meeting that way (Lead Teacher, Interview 2, p. 8).

> This last week the kids were talking in class meeting about the problem of so much talking going on in class. Some of the fourth graders were trying to come up with solutions for this problem. . . . So they begin to discuss solutions and one of the fifth graders came up with the idea, ‘Well remember if you go and have a friend help you with something or a friend help check your work off you are going to be tempted to talk to them more. So maybe you should talk to some one who's not a friend.’ And this was something I knew that was discussed the year before as a solution and a tactic that a fifth grader adopted and was able to pass on to a fourth grader (Assistant Teacher, Interview, p. 4).

In summary, problems were identified in ten of the lessons. Five of the ten were mathematics lessons categorized as a Type I. The teacher led the students through the method for solving the problem. Lesson F had a Type I problem and two Type II problems. Lesson Y had one Type II problem. Of the remaining, Lessons I and J each had one Type III, and Lesson P had two Type III problems. Examples of the students' problem solving in the lessons are presented below.

Student Problem Solving

There were 19 instances of students' problem solving, all occurring in Lessons F, I, J, and P. The problem solving in Lesson F occurred during the Type II problem situations and are described in the following section on problem solving transfer. The remaining instances of problem solving occurred in Type III problem situations. The following examples are representative of problem solving statements the students made:

> *Teacher*: You have to have recipes, money, you have to go shop for food, okay. And you have to prepare it. You also have to have dishes. You also have to set up a space to eat.
> *Student 11*: I thought that would be like Chinese food with chop sticks.
> *Teacher*: Chop sticks?
> *Student 11*: There is a Chinese place by my mom's office. I can ask them for some (Lesson J, p. 5).
>
> *Teacher*: Then there was the puppet show idea that is kind of cool. The living time line which is used with some kind of skit or just making a big paper time line like a big mural.
> *Student 2*: We could use the paper time line with a map so it goes all over the land (Lesson I, p. 6).
>
> *Teacher*: It looks like the top three are either a play or a fair. Let's see between those two and all the things we could do with each of those.
> *Student 15*: Why don't we do a play and a fair? (Lesson I, p. 12) Why don't we have a short skit in the fair? If we did the fair we could also do a play (Lesson I, p. 13).
>
> *Student 1*: I've got lots and lots of extra pencils. If any of you need them, I'm going to get rid of them. Also, at my house I have a

piggy bank full of erasers. But I would also be willing to donate those (Lesson P, p. 1).

Student 12: Maybe if you don't have two erasers but like five erasers, it almost means that you have something there you don't even know it. Maybe if it's yours you could donate it so that other people could use it (Lesson P, p. 2).

Student meeting leader: So, if you use a pencil, put it back in the black basket and if you need an eraser, take one but put it back. The other one is?
Student 15: Get supplies.
Student meeting leader: If the teacher gets supplies, get permission from the teacher and use it to get some.
Student 11: I had an idea where if we have a serious problem we should have a book with numbers so we could get a number on our eraser or book and then we could see who returned it (Lesson P, p. 2).

Problem solving occurred when the students (a) responded to the teacher's questions in the squaring of trinomials lesson (Lesson F), (b) brainstormed about the ancient China presentation (Lessons I and J), and (c) discussed solutions in the student led class meeting (Lesson P). A parent described her son's problem solving which illustrates transfer as well:

I think everyday [Student 13] exhibits some kind of problem solving. . . . I see a lot of that going on outside the school. When it comes to playing games or soccer and trying to figure out, 'How am I going to get past these two big guys and work my way up field? Do I have to share or pass the ball to someone else?' and you can see him think through it and afterwards I can ask him about it, 'Why did you do that?' And he will tell me the step-by-step process. 'This is what I had to do to get the ball down there' (Parent of Student 13, Interview, p. 3).

Another parent shared the following about her son's problem solving:

He researches things, collects the information, or he will talk about things and gather the facts and then prioritizes and then comes to some kind of solution. So I figure it's something that he's learned at Montessori just a way of talking to the problem and figuring it out. You know figuring out what he's going to do about it (Parent of Student 15, Interview, pp. 2-3).

These quotes describe students' problem solving but also show parent awareness of the student's problem solving ability. Next, each of the lessons was examined to determine if problem solving transfer was evident.

Problem Solving Transfer

Using Mayer and Wittrock's (1996) definition, "A problem solver uses a previous experience with one kind of problem to help solve a different kind of problem" (p. 48), three instances of problem solving transfer were identified in two lessons, Lessons F (Type II) and J (Type III).

In Lesson F, the teacher, using inductive inquiry, taught the students graphing of trinomials. When asked what the graph would look like with ten digits the student responded:

> *Student 3*: It would be billions or something.
> *Teacher*: You could probably do it. It would need a big piece of paper. You ought to try it. But you could do it, you know how. Why don't you try it? It would be awesome. We could put it up in the hall! Do a couple of trinomials, one today and then one tomorrow. When you have your work done you can try a pentinomial. What would a pentinomial be?
> *Student 9*: Five digits times five digits (Lesson F, p. 3).
>
> *Teacher*: What if you had a trinomial times a binomial?
> *Student 3*: "Just 2 times 3."
> *Teacher*: Good, and now you thought when you guessed that a trinomial times a trinomial would have 1000s instead of 100s but it actually goes up by 2. Let's do some predicting. Let's imagine we have a quadrinomial. What would our graph look like? What would go here?
> *Student 9*: 1,000s (Lesson F, p. 4).

When brainstorming about publications for the ancient China presentation, a student had the following suggestion:

> *Teacher*: Well, we had talked about maybe doing it so this group will have to look at how much or many we would have to print. And what the cost is going to be and we maybe will have to talk to Miss Donna and ask if we could have some paper to do that or . . .

> *Student 11*: It doesn't have to be a big newspaper. Maybe it could be a newspaper while we do the fair and then have a little flyer just like I made for the independent study program (Lesson J, p. 9).

In these instances the students illustrated transfer of an experience with a previous problem to solve a new problem. In Lesson F the student had learned the procedure for squaring trinomials and he used this problem solving knowledge to successfully respond to her questions about pentanomials and quadronomials. Leading up to the instance in Lesson J, the students and teacher have been discussing whether to do a newspaper, a brochure and invitation or some combination of the three. Student 3 draws on her past experience of creating a flyer for her independent research presentation to suggest a solution.

The following illustrates the students' ability to use past experiences to organize information and create a framework for approaching a new task.

> We were going to study the millennium a little bit, and we had to discuss how we would go about studying the millennium because it is pretty broad topic. . . . They finally started grouping it into needs of people: 'Hey, we need to study their needs.' Then they started naming those needs which is what they had done in the China fair which is what they had done in other studies of civilizations that they had done in other years. And also in what they do in third grade, second and first grade when they study the different needs of people during different time periods. So it is really the same thing they have done all along. And they kind of approach I guess a new study-- when I said let's study the millennium, what do we want to study, they approached it with that same frame work. They started naming things and then started realizing, let's group these into needs of people (Lead Teacher, Interview 2, pp. 5-6).

The lead teacher provided the following examples of how the students used the process for solving problems in a class meeting.

> Another time they used their prior experiences in something new is their class meeting format that they have had since first grade. . . . A couple weeks before the trip, something had come up in the classroom. I can't remember what it was. It was at the end of the day, and it was about ten children that were involved, and they had some problem or some concern and they said, 'What are we going to do about this?' And I said, 'Why don't you have a meeting?'

> And they went over and had a meeting like a class meeting. They elected someone to be the leader for that time. And that person facilitated the meeting . . . and they were able to share and remembered the format of sharing all the possible solution and discussing the solutions, and then they voted on a solution.
>
> Then they decided to implement that solution and they went through all of that process and then I came back and checked with the leader, and the leader shared what the solution they came up with was and they had done it themselves. So they do use that--they will slip into that format even though it is not an official time, they just know how to run a meeting that way (Lead Teacher, Interview 2, p. 8).

> This last week the kids were talking in class meeting about the problem of so much talking going on in class. Some of the fourth graders were trying to come up with solutions for this problem. . . . So they begin to discuss solutions, and one of the fifth graders came up with the idea, 'Well remember if you go and have a friend help you with something or a friend help check your work off, you are going to be tempted to talk to them more. So maybe you should talk to some one who's not a friend.' And this was something I knew that was discussed the year before as a solution and a tactic that a fifth grader adopted and was able to pass on to a fourth grader (Assistant Teacher, Interview, p. 4).

These quotes illustrate problem solving transfer. The students used previous problem solving to solve new problems. The lead teacher also described an example of problem solving transfer that occurred in Lesson Y on finding the volume of prisms, cones and pyramids.

> So when we got to that point we sat down with the lesson and I think (Student 1) automatically said, 'Oh, I know, just like we divided the prism volume by three to get the pyramid, I think we will have to divide the cylinder by three to get the cone's volume.' Which was exactly right. (Lead Teacher, Interview 3, p. 3)

The lead teacher described another instance that occurred during a math lesson with fourth grade level students:

> At the beginning we started looking at fractions and they had been dividing a fraction by a whole number and now they were going to start dividing a fraction by a fraction. . . . Then they realized that they had seen something similar and one of them said, 'Oh, wait, this is what I remember from my book, there are arrows. I never understood what those arrows meant but now I see what they apply to.' So they kind of put those pieces together, the different things they had learned before about division because it is just like the test tubes. And the different things they had learned about fraction

> equivalency they naturally were able to do in making exchanges with the pieces (Lead Teacher, Interview 1, p. 6).

The teacher's description illustrates how the students used previous knowledge in dividing whole numbers with fractions to solve the problems of dividing fractions by fractions.

In summary, there were a total of 19 instances of problem solving and three instances of problem solving transfer in the lessons. All of these instances occurred in the four lessons that were categorized as Type II and Type III problem situations. There were also instances of problem solving and problem solving transfer described in the interviews. However while reviewing the lessons, it became apparent that the concept of problem solving transfer by itself did not capture the various dimensions of transfer. In some cases, the children used previous knowledge to acquire or understand new knowledge (knowledge transfer) without necessarily solving a problem (problem solving transfer).

Knowledge Transfer

Knowledge transfer occurred more frequently than problem solving transfer, in 11 of the 24 lessons, or in almost 50% of the lessons. In these 11 lessons there were 25 instances of knowledge transfer. Seventy-two percent of the knowledge transfer instances occurred in history lessons, 12% in mathematics lessons, and 8% of the instances in a reading lesson and 8% in a geography experiment (see Table 3).

For example, in Lesson O the following four instances of knowledge transfer occurred. In this prehistory lesson, the students were learning about the Triassic period in the Mesozoic era of prehistory.

> *Teacher*: Now, what do you think the climate is going to be like? I know you didn't take notes, but what do you think the climate is going to be like? We just finished an ice age and its all melted off.
> *Student 12*: It's probably going to warm but not hot.
> *Teacher*: Warm enough to melt something, right?
> *Student 12*: Right, not like it is in Waco in the summer (Lesson O, p. 5).

> *Teacher*: Tell us what the name means, where the name Triassic came from. But before you tell us, let's see if the other three can guess. Guys that didn't take notes, see if you can guess what Triassic means. Have you ever heard the prefix tri before?
> *Student 7*: Three
> *Student 14*: Like tricycle (Lesson O, p. 16).

These student used similes to illustrate the transfer of knowledge.

> *Teacher*: Plateosaurus' fossils have been found in Germany, Argentina, China, South Africa and North American. Let's look at that for a second, Germany, Argentina, China, South Africa, North America, something about that look strange to you?
> *Student 13*: That's why they know about Pangea (Lesson O, p. 14).

This student connected the discussion of Plateosaurus' fossils to an earlier discussion on Pangea.

> *Teacher*: (*In discussing the meaning of the word, Triassic*) Well, three layers, fossils are in rocks, right. And it comes from the Latin word for three.
> *Student 7*: Almost every single work we have comes from the Latin language (Lesson O, p. 16).

In Lesson O, student 7 transferred previous knowledge about English words originating from Latin to this discussion. In Lesson W the teacher facilitated a discussion with five 4th level students on the Jurassic period. This lesson followed the prehistory lesson on the Triassic period.

> *Teacher*: Did you find anything on plants,(Student 6)?(Student 14)? Okay, there were plants called cycads.
> *Student 8*: They were in the Triassic (Lesson W, p. 4).

> *Teacher*: Amphibians, were there any amphibians? (Student 14) what did you find out?
> *Student 14*: Frogs and salamanders
> *Teacher*: Good, frogs and salamanders.
> *Student 7*: We had salamanders in Triassic (Lesson W, p. 5).

In response to the question ‘Can you think of a time when already knowing something has helped you to learn something new?’ students made comments such as:

> Last year I did an independent study about rockets and that gave me an idea of what to do this time--with pictures and paragraphs. And then in 1,2,3 and 4th grade, I did some research on animals and that led to this. (Student 10, Interview, p. 2)

> Like in research. Like finding shortcuts to doing things. Say you found the shortcut on how to find research real fast instead of having to find it and interpret the information. It would help you do other research along the way. Also in finding area where you would take a long time--you would find the area of the rectangle before you could find the area of a triangle or rhombus. You have to learn the basic things first. (Student 3, Interview, p. 2).

> With decimals and if you know how to use the words and stuff then you can do the problems a lot easier. There is a thing we do at the beginning that shows you the placement that kind of helps you to do all the rest of them--the addition, the subtraction, multiplication, division--in just that one step at the beginning helps you deal with the rest of it. We go from real easy like addition problems that will have like 30, we will have to do and then the subtraction and multiplication, division. What I'm on is to organize numbers into categories and things with the lowest, middle and then highest. Or it will be which number is in the 1000s place or what digit is in the 5 place and things like that. We just move on level by level (Student 6, Interview, p. 2).

These three examples illustrate the students’ ability to transfer knowledge from one situation to another. Parents provided comments such as:

> We were at the Art Center recently, and they had little classes and seminars that children can attend and up on the wall was a poster of a plate. And she said, ‘Mom, that is from the so-and-so dynasty.’ And I said, ‘What . . . how do you know that?’ I had no earthly idea which ancient Chinese Dynasty this plate had come from and sure enough when I looked down at the minuscule print at the very bottom, she was right. I was just really amazed (Parent of Student 15, Interview, p. 2).

> There are many times every week that I will notice him using a concept and applying it in a totally different situation but using that same sort of thinking process to figure it out. Or using a concept, and the one I'm remembering was the concept of indigenous to an area, and now I can't remember just how exactly he used that in another area but what was

> really fascinating to see how he was making that connection and it does happen regularly at the house (Parent of Student 16, Interview, p. 2).

These parents identified their children exhibiting knowledge transfer in settings outside the classroom.

In summary, problem solving, problem solving transfer, and knowledge transfer did occur in this Montessori classroom as well as outside the classroom. The 19 instances of problem solving and three instances of problem solving transfer in the lessons occurred in four lessons that were categorized as Type II and Type III problem situations. The content of these lessons (F, I, J, and P) was mathematics, ancient China research presentations, and a student led class meeting. In the lessons there were a total of twenty-five instances of knowledge transfer. These instances occurred in 11 of the 24 lessons. The content of these lessons ranged from history to mathematics, reading, and geography. The knowledge transfer occurred in Type I, II, and III problem situations. Fourteen instances of problem solving, 11 problem solving transfer instances, and 47 knowledge transfer instances were described in the interviews with the students, teachers, and parents. These instances occurred within the classroom as well as outside the classroom.

3. What are the factors that influence problem solving transfer in a Montessori classroom?

Nineteen instances of problem solving occurred in four lessons (F, I, J, and P). Three instances of problem solving transfer occurred in Lessons F and J. Twenty five instances of knowledge transfer occurred across 11 lessons (N, L, O, G, H, W, E, I, J, M, and Y). In order to determine what influenced this problem solving and transfer, the following teacher instructional strategies, student factors and curriculum factors were examined.

3.1. What teacher instructional strategies influence problem solving transfer in a Montessori classroom?

These four teacher instructional influences were examined: teaching methods, levels of questions, teacher's sense of self efficacy, and student opportunities for problem solving and transfer. The teaching methods used in the lessons were categorized by the type of strategies employed. The methods were examined to see if there was a relationship between the teaching method used in the lessons and the amount of problem solving and transfer in the lessons. Due to the belief that using higher level questioning will lead to better problem solving, the questions and responses in the classroom were also analyzed and categorized according to the FIAC-M.

The teachers' self-efficacy for problem solving was also examined. It was assumed that teachers possessing strong self-efficacy for problem solving will more likely have a positive influence on student problem solving. The last influence examined was the student opportunities to problem solve and transfer. The opportunities were analyzed by (a) counting the number of total interactions in each of the lessons in which problem solving and/or transfer occurred, (b) identifying which students were present in those lessons, and (c) dividing the number of student instances by the total number of interactions in those lessons. The results of the four instructional influences are described below.

Teaching Methods

Using the Tomlinson et al. (2002) categories, the primary teaching methods or strategies used in each lesson are listed in Table 6. A total of 11 different methods were present in the lessons. These methods ranged from more teacher-centered strategies that allow less student inquiry and independence (i.e., direct instruction) to more student centered strategies that encourage inference and independence (i.e., problem-based learning). Content area instruction, graphic organizer and strategy-based instruction accounted for 75% (n=18) of the lessons. Twenty nine percent (29%, n = 7) of the lessons used the more student centered approaches of inquiry-based instruction (Lessons F, G, and M), problem-solving/problem-based learning (Lessons I, J, and P), and independent study (Lesson X).

All of the problem solving and problem solving transfer instances occurred in the more student centered approaches. Thirty six percent (n = 9) of the knowledge transfer instances occurred in the more student centered methods of inquiry-based learning and problem-based learning. The remaining knowledge transfer instances (64%, n = 16) occurred in the more teacher centered methods of strategy-based instruction and content area instruction.

Flanders Interaction Analysis Categories-Modified (FIAC-M)

The 24 classroom lessons were analyzed according to the FIAC-M interactions. Teacher-student, student-teacher, and student-student interactions were coded. The teacher-student interaction was defined as a question posed by a teacher and a student or students respond to that question. Interactions, which

Table 6

Teaching Methods

Lesson	Method
N	Content Area Instruction, Graphic Organizer
L	Content Area Instruction, Graphic Organizer
S	Demonstration/Modeling
O	Content Area Instruction, Graphic Organizer
G	Inquiry-Based Instruction, Cooperative Learning
H	Content Area Instruction, Graphic Organizer
W	Content Area Instruction, Graphic Organizer
E	Strategy-Based Instruction
R	Content Area Instruction, Graphic Organizer
U	Strategy-Based Instruction
F	Inquiry-Based Instruction
I	Problem-Based Learning
V	Strategy-Based Instruction
J	Problem-Based Learning
A	Direct Instruction
Z	Demonstration/Modeling
B	Concept Attainment, Graphic Organizer
AA	Concept Attainment
M	Inquiry-Based Instruction
P	Problem Solving Learning
D	Strategy-Based Instruction
X	Independent Study
C	Concept Attainment
Y	Strategy-Based Instruction

were initiated by a student query and followed by a teacher or student response, were categorized as well.

Using the videotaped transcription while watching the video, every question and response of students and teachers participating in the study were coded according to Bloom's cognitive taxonomy. Eleven percent (11%) of the total coded interactions were not included in the final categorizing because the students were not identifiable on the videotape or they were not participating in the study. A total of 1210 questions and responses were coded for the participants. It should be noted that the total number of queries and responses for each type of interaction were not equal. At times a question was asked and no response was given or at other times multiple responses were given for one question.

The results showed that 100% of the interactions were categorized at the knowledge, comprehension, and application levels according to Bloom's cognitive taxonomy. No queries or responses were categorized as higher-level interactions. Approximately four out of five (84.2%) of the classroom interactions were teacher questions followed by student responses. Of those interactions, 67.4% (n = 687) were categorized at the knowledge level, 26.9% (n = 274) at the comprehension level, and 5.7% (n = 58) at the application level.

Student questions-teacher responses comprised 12.2% (n = 221) of the total number of interactions. The majority, (68%, n = 100), of these interactions were categorized at the knowledge level with 21.8% (n = 32) at the comprehension level, and 10.2% (n = 15) at the application level. The student question-student response interactions, accounted for 3.6% (n = 44) of the total number of classroom interactions. Approximately eighty nine percent (88.6%, n = 39) of those interactions were categorized at the knowledge level, 9% (n = 4) at the comprehension level, and 2.2% (n = 1) at the application level.

Across all types of interactions, 68.3% (n = 826) were categorized at the knowledge level, 25.6% (n = 310) at the comprehension level, and 6% (n = 74) at the application level. Of note, at the comprehension level and the application level the total number of student responses exceeded the number of teacher questions, (8.6%, n = 20 and 5.2%, n = 12 respectfully). In contrast, at the knowledge level there were an almost equal number of teacher questions (50.9%, n = 350) and student responses (49.1%, n = 337).

The instances of application level questions and responses by lesson are provided in Table 7. In the lessons where there was problem solving and problem solving transfer (Lessons F, I, J, and P), 47.8% (n = 11) were application level teacher questions and 58.3% (n = 21) were application level student responses. In Lesson N where the highest number of instances of knowledge transfer (20%, n = 5) occurred, there were a total of 14 (18.9%) application questions and responses.

Of particular interest, two (66.6%) of the three instances of problem solving transfer were also categorized as application level responses. Both instances occurred in Lesson F. Five (26.3%) of the 19 instances of problem solving were also categorized at the application level of questions and responses. These occurred in Lessons F, J, I, and P. Five (20 %) of the 25 knowledge transfer instances were also categorized at the application level. Three (60%) of these five occurred in Lesson N.

Table 7

Student and Teacher Questions and Responses at Bloom's Application Level by Lesson

Lesson	Question	Response	Lesson	Question	Response
N	TTTTT SS	TT SSSSS	V		
L	TT	TSS	J	TSS	TTSSS
S			A		
O	T	SSS	Z		
G	T	S	B	TT	SSSSSSS
H	T	SS	AA		
W		S	M		
E			P		S
R			D		
U			X		
F	TTTTT	SSSS	C	S	
I	TTTTTSS	TTTSSSS SS	Y		S

T = one instance of a teacher question or response
S = one instance of a student question or response

The following are examples of questions and responses that were categorized as application level interactions.

> *Teacher*: What ideas do you have about presenting our ancient China information? (application question)

Students not participating in the study suggested a newspaper, a fair, an art museum, a skit, and a movie. The following responses were offered by students participating in the study:

> *Student 4*: (*referring to his previously written list*) I had a timeline and field trip--have all the classes walk through.
> *Student 10*: We could simulate an airplane.
> *Student 11*: We could make a magic school bus.
> *Student 4*: We could make a map of China.
> *Student 15*: A skit or someone that talks about their dynasty on a timeline, a map of the dynasty (all application responses) (Lesson I, pp.1-2).

After the students had shared their top five choices for how to present the information on ancient China, the teacher tallied the results on the board and said:

> Teacher: It looks like the top three are either a play or a fair. Let's see between those two and all the things we could do with each of those.
> *Student 15*: Why don't we do a play and a fair? (application question and problem solving)
> Teacher: Okay, if we had either a fair which is kind of like a simulation. In this you would probably be dressed in the clothing. Or we could do some kind of play. Under the play (*referring to the listing*) we had a TV show. There was a movie, what else? We could brainstorm a play (application response). What kind of a play? (application question)
> *Student 11*: Why don't we have a short skit in the fair? If we did the fair we could do also a play (application question and problem solving).
> Teacher: It sort of would be a skit but it wouldn't be performing. Instead you would be walking around with all of the people talking to them. It would be like (Student 9) and (Student 3) when they came in.

The teacher was referring to a recent incident when these two students were portraying characters. When she made this statement, the students exclaimed that they were not (Student 9) and (Student 3), so the teacher said:

> *Teacher:* I'm sorry, Einstein or Squanto were here. They just looked like (Student 9) and (Student 3)--so similar (application response). Should we vote between the two or do you just want to decide? (application question) (Lesson I, pp. 12-13).

The students voted to do the fair, and the discussion turned to the types of committees they would need and what they would do.

> *Teacher*: Okay, if we look at models we are talking about models of the Great Wall. Okay, what else would we have models of? (application question)

Student 2: Houses, clothing (application response)

Teacher; Are we going to have a big room where we have all this stuff going on or are we going to make it like we invite a few people at a time and take them on a tour? (application question)

Teacher: We could take ten or fifteen at a time or a whole class at a time maybe.
Student 4: Take the sixth grade around to our booths (application response).

Problem Solving and Thinking Processes

The two teachers' scores on the Problem Solving and Thinking Processes scale indicated they had similar feelings about their self-efficacy for problem solving. After converting their raw scores to *z* scores, the lead teacher's score ($z = -1.21$) fell two standard deviations below the mean ($z = -.931$), and the assistant teacher's score ($z=-0.740$) fell one standard deviation below the mean for the student and teacher scores.

Student Opportunities for Problem Solving and Transfer in Lessons

In the videotaped lessons 19 instances of problem solving, three instances of problem solving transfer and 25 instances of knowledge transfer were identified. All of the instances occurred in one half (50%) of the total number of lessons. Since all the students were not in every lesson, there was not an equal opportunity for them to participate.

In order to equalize all the students' opportunities to demonstrate problem solving and transfer, the following interaction was computed. Each of the twelve lessons that had at least one instance of problem solving or transfer was examined to determine which students were present in the lesson. Next, the total number of FIAC-M interactions by lesson were totaled by lesson per student. In other words, Student 1 participated in Lessons M, Y, and P, and there were a total of 69 FIAC-M interactions in those lessons. Student 1 problem solved a total of two times. Therefore, Student 1 had a problem solving opportunity rate of .029 (see Table 8).

Table 8

Student Knowledge Transfer, Problem Solving, and Problem Solving Transfer Opportunity Rate

Student	Knowledge Transfer	Problem Solving	Problem Solving Transfer
1		.029	
2	.008	.012	
4	.009	.004	
5	.012		
7	.012		
9	.008	.016	.016
10		.018	
11	.018	.018	.003
12	.002	.002	
14	.002		
15	.013	.004	
16	.019		

Opportunity rate means that for every 100 opportunities Student 1 would verbally problem solve about 3 times. Students 9 and 11 problem solved and demonstrated knowledge as well as problem solving transfer. Four of the students (Students 3, 6, 8, and 13) did not verbalize any statements that were categorized as problem solving or transfer.

In summary, problem solving and problem solving transfer occurred in the more student-centered lessons, specifically in those lessons with inquiry-based, problem-based and problem solving learning. While knowledge transfer did occur in student-centered approaches, the majority of instances occurred in more teacher-centered lessons. The FIAC-M results indicate a positive relationship between higher level of questioning/responses and (a) problem solving and problem solving transfer and (b) student-centered teaching methods.

3.2 What student characteristics influence problem solving transfer in a Montessori classroom?

The influence of three student characteristics was examined: (a) application level questions and responses by student, (b) student scores on the Problem Solving and Thinking Processes scale, and (c) student intelligence.

Flanders Interaction Analysis Categories-Modified

The number of application questions and responses by student was analyzed and the results are listed in Table 9. While only four students (4, 7, 11, and 15) generated seven application questions, all of the students except two had at least one application level response. Student 4 asked 42.9% (n = 3) of the application level questions. Four students (2, 4, 10, and 11) provided 44.4% (n = 16) of the application level responses. Students 4 and 11 had the highest number of application questions and responses (n = 7, 6 respectively).

Of note, Student 11 also had the highest total problem solving and transfer opportunity rate (see Table 8). Students 6 and 8 did not ask a question or respond in a manner that was categorized at the application level. Nor did either of these students verbally problem solve or transfer in the lessons.

Problem Solving and Thinking Processes

The students' scores on the Problem Solving and Thinking Processes scale indicated limited variance in their responses. After converting their total raw

Table 9

Student Questions and Responses at Bloom's Application Level

Student	Application Level	Student	Application Level
1	R	9	RRR
2	RRRR	10	RRRR
3	RRR	11	QQRRRR
4	QQQRRRR	12	RR
5	RRR	13	R
6		14	R
7	QRRR	15	QRRR
8		16	R

Q = one student question at the application level
R = one student response at the application level

scores to z scores, 75% of the students scored within 1 SD of the mean. The students with the highest scores were Students 4, 12, and 14 and Student 7 had the lowest score. Therefore according to the results on this scale, these students, for the most part, have positive self-efficacy toward problem solving.

Intelligence

The students' intelligence was assessed with the TONI-3. This individually administered test was used because of its strong emphasis on measuring problem solving ability (Brown, Sherbenou & Johnsen, 1997). The students' quotient scores ranged from a low of 78 (Student 4) to a high of 142 (Student 5) with a mean of 100.5 (SD = 16.75). The students' quotient scores are listed in Table 10. In this study the positive relationship between intelligence and problem solving and transfer is not evident. Student 11 who had the highest total opportunity rate (see Table 8) and interview instances (see Table 4) for problem solving and transfer and the second highest number of application questions and responses scored the second lowest (Q = 82) on the TONI-3. Conversely, Student 5 who had the highest TONI-3 quotient score of 142 had a very low problem solving and transfer opportunity rate, very few interview instances, no application questions and only three application level responses.

Table 10

Student Quotient Scores on the TONI-3

Student	TONI-3 Quotient	Student	TONI-3 Quotient
1	110	9	118
2	100	10	96
3	115	11	82
4	78	12	84
5	142	13	97
6	91	14	115
7	105	15	89
8	84	16	102

To summarize, Student 11 had the highest total problem solving and transfer opportunity rate as well as the second highest number of application questions and responses. Therefore, these results support the general findings indicating a positive relationship between the level of questioning/responses and problem solving and transfer. The results on the self-efficacy scale indicated that generally the students felt positive about problem solving. The findings regarding intelligence did not show evidence of a positive relationship between TONI-3 scores and problem solving and transfer. Interestingly, Student 4 whose quotient score of 78 (the lowest in the class) had one of the highest scores on the Problem Solving and Thinking Processes scale, the greatest number of application level questions/answers, the sixth highest knowledge transfer and problem solving opportunity rates.

3.3. What curriculum characteristics influence problem solving transfer in a Montessori classroom?

The influence of two curriculum characteristics were examined (a) types of knowledge, and (b) academic engaged time.

Types of Knowledge

The three types of knowledge were present in varying degrees in the lessons (see Table 11). Declarative knowledge, the knowledge of facts, names, concepts, and events (Schunk, 2000), was used in all of the lessons. In 11 (46%) of the lessons, declarative was the only type of knowledge. Procedural knowledge, the knowledge of how to do something, was used in 13 (54%) of the lessons. The procedural knowledge was coupled with declarative knowledge in those lessons. Strategic knowledge, knowing when to use information (Gunter, Estes & Schwab, 1999), was present in three (12%) of the lessons (E, F, and P). Declarative and procedural knowledge were present in those lessons as well.

Academic Engaged Time

Nine academic engaged time observations were completed over a period of three months. These observations were done in the classroom at varying times of the day. The group engagement coding consisted of counting the number of students visible in one pass and then counting the number of students nonengaged in a second pass. A total of 540 observations for 135 minutes were collected. The average percentage of student engagement was 93.33% across all

Table 11

Types of Knowledge in the Lessons

Lesson	Types of Knowledge	Lesson	Types of Knowledge
N	Declarative	V	Declarative, Procedural
L	Declarative	J	Declarative, Procedural
S	Declarative, Procedural	A	Declarative
O	Declarative	Z	Declarative
G	Declarative, Procedural	B	Declarative, Procedural
H	Declarative	AA	Declarative
W	Declarative	M	Declarative
E	Declarative, Procedural, Strategic	P	Declarative, Procedural, Strategic
R	Declarative	D	Declarative, Procedural
U	Declarative, Procedural	X	Declarative
F	Declarative, Procedural, Strategic	C	Declarative, Procedural
I	Declarative, Procedural	Y	Declarative, Procedural

observations. The nine observations ranged from a low of 86% to a high of 96.23% of the students engaged for a 15 minute period.

In summary, all three types of knowledge were present in two (50%) of the lessons (F and P) where problem solving and problem solving transfer occurred. In the other two lessons (I and J) where problem solving and problem solving transfer occurred, declarative and procedural knowledge were used. Knowledge transfer occurred in lessons where only declarative knowledge was used as well as in lessons where procedural and strategic knowledge were used.

In Lesson N where the greatest number of knowledge transfer instances occurred, only declarative knowledge was used. In reference to the influence of engagement, the very high percentage indicates the environment was one in which the vast majority of students stayed on-task with their learning.

CHAPTER FIVE

Conclusions and Implications

With the increasingly competitive workplace and the need for an adaptive workforce, the role of education in preparing the workforce of tomorrow is critical. Students need to know how to transfer knowledge and skills learned in one setting and successfully apply them in a variety of situations. Students must be equipped with the ability to transfer what they have learned to solve problems. Although teaching problem solving transfer is of critical importance to educators, this transfer does not occur as often as one would think. Therefore, specific models of education should be examined to determine if they contain the necessary skills and approaches to enhance thinking and problem solving. Montessori is a model of education that stresses the teaching of problem solving.

Summary of the Results

In this study, the purpose was to examine the use of problem solving strategies within the Montessori model of learning and to determine if problem solving and transfer occurred. The primary sources for data were 24 videotaped lessons in a Montessori fourth through sixth grade level classroom and audiotaped interviews with key participants. Additional data were collected from relevant documents, TONI-3 and Problem Solving and Thinking Processes scores, FIAC-M teacher-student interactions, and academic engaged time in the classroom. Three research questions guided this study.

Question I

Question 1 asked what Montessori model characteristics are similar to those characteristics reported in the problem solving research that facilitate transfer. The literature review in Chapter 2 identified certain instructional strategies that encourage transfer and have a positive effect on the quality of the process. As evidenced in Chapter 4, the key strategies of (a) variety of learning opportunities, (b) quality learning experiences, (c) depth of learning, and (d) metacognitive awareness were present in the videotaped lessons, the interviews, and the relevant documents. Therefore, this study concluded that the Montessori model of learning, as implemented in this setting, incorporated these instructional and curriculum strategies in the classroom.

Question 2

Question 2 asked in what ways does problem solving within the Montessori classroom transfer. Examination of the videotaped lessons and the audiotaped interviews indicated instances of problem solving and problem solving transfer. Knowledge transfer was evident as well. Specifically, 19 instances of problem solving, three instances of problem solving transfer and 25 instances of knowledge transfer were identified from the content analysis of the verbal responses in the 24 lessons. The researcher identified additional instances in the analysis of the student, teacher, and parent interviews. Fourteen instances of problem solving, 11 instances of problem solving transfer, and 47 instances of knowledge transfer were described in the interviews.

Question 3

Question 3 asked what teacher, student, and curriculum factors influenced problem solving and transfer. It became clear that certain characteristics influenced the opportunities for problem solving and transfer in the lessons. For example, where problem solving and problem solving transfer occurred, the following teacher and curriculum characteristics were present in the lessons:

- A problem was evident;
- Type II or Type III problem situations;
- Student centered instructional methods such as inquiry-based, problem-based, and problem solving learning;
- Higher level teacher/student questions and responses;
- Many opportunities for problem solving and transfer to occur;
- Declarative, procedural and at times, strategic knowledge were used.

Knowledge transfer instances occurred in lessons that were not as specifically defined by these characteristics. Knowledge transfer occurred more than four times as often as problem solving transfer. Knowledge transfer occurred in almost half (11) of the total number of lessons while problem solving transfer occurred in only two of the lessons. Instances of knowledge transfer were described in the interviews almost four times more often than problem solving transfer.

Regarding the student factors, the student (5) who had the highest TONI-3 quotient score had a very low problem solving and transfer opportunity rate, very few interview instances, no application level questions, and only three application level responses. Conversely, the student (4) with the lowest TONI-3 quotient score had one of the highest scores on the Problem Solving and

Thinking Processes scale, the greatest number of application level questions/answers, the sixth highest knowledge transfer and problem solving opportunity rates. These findings did not show evidence of a positive relationship between intelligence, as measured by the TONI-3, and problem solving and transfer.

The student (11) with the highest total problem solving and transfer opportunity rate also had the second highest number of application questions and responses. These results indicated a positive relationship between the level of questioning/responses and problem solving and transfer.

Relationship to the Research Literature

As evidenced in this study, there is a strong relationship between the characteristics of the Montessori model of education and the instructional influences and strategies that facilitate problem solving and transfer. Although these influences and strategies were present, the instances of problem solving and transfer were limited. As reported in the literature, transfer does not occur often. Mayer and Wittrock (1996), in their seminal review stated, "Problem solving transfer seems rare" (p. 51).

While most cognitive psychologists study transfer as a general concept, Mayer and Wittrock (1996) distinguished between knowledge and problem solving transfer. That distinction was important to this study. Early in the analysis of the videotaped lessons and the audiotaped interviews, the researcher struggled with the defining attributes of problem solving transfer. Over time it became apparent that the concept of problem solving transfer by itself did not capture the various dimensions of transfer. In many cases the students used previous knowledge to acquire or understand new knowledge without necessarily solving a problem.

Research Settings

The vast majority of the studies on transfer have been conducted in laboratory situations and other controlled settings. Often times the participants in the studies have been college students or adults. Capturing transfer, particularly young children's problem solving, has met with varied success. Campione, Shapiro, and Brown (1995) suggested that laboratory experiments have particular limitations when conducted with children and recommended a more naturalistic environment for study. This research studied transfer with elementary age students in the natural setting of a classroom.

Campione and colleagues (1995) described transfer as essentially a theoretical term that has been applied to a range of phenomena. These authors acknowledged the difficulty in recognizing transfer in the context of classrooms. The best way to operationalize transfer in a "real setting" such as a classroom is not always evident. In their recent study on learning in an after-school computer club, Mayer, Quilici, and Moreno (1999) indicated further research was needed to determine the factors that promoted problem solving transfer. This research of the Montessori classroom contributes to the field by studying transfer within the context of an elementary classroom and by providing a framework for examining the factors which enhance problem solving.

Instructional Strategies

This study illustrated that even when the instructional strategies are conducive, many opportunities were still needed for problem solving and transfer to occur. Obviously, a problem must be evident in a lesson for problem solving to occur. If the ability to problem solve was an instructional goal, teachers must provide the opportunity to solve problems. More student-centered lessons encourage problem solving and transfer. Furthermore, the problem situations needed to be more open-ended (i.e., Problem II and above) than ones where the students are given the parameters (i.e., the problem and process) and just have to find the solution. Engagement in the learning process in thoughtful and interactive ways is necessary for problem solving and transfer to occur in the classroom.

The cognitive level of teacher-student interactions influenced problem solving and transfer in this study. The findings suggested that to encourage these abilities, teachers needed to use at least application level questions with students. Instances of problem solving and transfer appeared to be positively related to the number of application level questions and responses in a lesson. In fact, a number of application level interactions were also categorized as instances of both problem solving and transfer. These findings also suggested the use of procedural and strategic knowledge in instruction to encourage problem solving and transfer. Declarative knowledge is necessary, but perhaps, not enough when used alone, to encourage problem solving and problem solving transfer.

Research indicated that transfer tended to be domain-specific. A person who was highly skilled in one domain does not necessarily transfer that skill to a different domain or field of study (Mayer & Witttrock, 1996). Previous research also indicated that the majority of transfer is "low road" or *near* transfer. In this type of transfer, the new learning situation was closely connected with the prior knowledge. The current study supports those findings.

In the three problem solving transfer instances the domains were highly related. Specifically, the two instances that occurred in Lesson F were examples of extending the squaring of trinomials to squaring pentanomials and to squaring quadronomials. The original problem solving as well as the problem solving transfer occurred in the same domain of mathematics. In the third instance the student draws on her past experience of creating a flyer for her independent study presentation to suggest a solution for what the class should create for the ancient China Fair presentation. Both the original problem solving and the problem solving transfer focussed on creating a document for a research presentation.

Student Factors

The student characteristics that were examined indicated a positive relationship between the level of students' questioning/responses and problem solving and transfer. This supports the research literature on using metacognitive strategies to increase thinking skills (Halpern, 1998; Mayer and Wittrock, 1996). In addition, the research findings on problem solving self-efficacy (Armstrong, 1998; Schunk, 1994) were upheld to some extent in this study.

These findings did not show evidence of a positive relationship between intelligence and problem solving and transfer. Possible explanations relate to the following factors. The student with the highest intelligence score was probably the quietest and most soft-spoken student in the classroom. While the student may have been mentally problem solving, she may have chosen not to share the information verbally. It is also possible that the student's verbal responses were not always picked up by the microphone and consequently, not part of the transcriptions. Another explanation may relate to the nature of the problem solving that occurred in many of the lessons. It is possible that the level of complexity of many of the problem solving and transfer instances did not require a high intelligence quotient.

A final explanation may relate to the teacher-student roles and interpersonal relationships within the classroom. Since Montessori classrooms are multi-aged environments, many of these students had been together for several years and may have been with these teachers the previous year. It seems reasonable that over time behavior patterns would have been established that impacted the students' participation in discussions. Perhaps the teachers tended to call on the talkative, demonstrative students more often and on those who volunteer.

Limitations

As with any research, there were limitations of this study. The key limitations included the private school setting, small sample size, no direct control group, no ethnic or socio-economic diversity, and the use of a single elementary classroom. Another important limitation was that the Montessori model of learning, as implemented in this setting, may not represent all Montessori schools. Due to the nature of a case study design, these results cannot be generalized to a larger population or other situations.

Another important limitation relates to the way problem solving and transfer were measured. In many previous studies, the emphasis has been on demonstrating the skills. In this study the problem solving and transfer instances were only measurable if the participants responded verbally. Perhaps more instances occurred within the classroom than were documented. Since the Montessori model of learning promotes learning through a highly structured curriculum, there may have been missed opportunities for problem solving and transfer.

Another related factor was the on-going challenge of video recording in a classroom. At times, the researcher did not capture the entire lesson or successfully record all the verbal interactions within the lesson. This points to the unskilled abilities of the researcher in collecting video data and the time constraint of not being in the classroom at all times. A more systematic approach to capturing the lesson data would have strengthened the study.

A final limitation may have been the way problem solving transfer and knowledge transfer were characterized. For this study, the traditional view of transfer was adopted. Perhaps Campione and colleagues' (1995) broader perspective of transfer as *understanding* would have better captured the learning phenomena in this classroom.

Directions for Future Research

Given the importance of this topic and the limited number of previous studies that were conducted in natural settings, it is extremely important to continue this type of research in classrooms. Using this framework, these findings could be explored with a larger population as well as a more diverse population. An important contribution would be to use this framework in examining students and teachers in classrooms representing other models of education, and with other grade levels, particularly middle school and high school.

Future research on the developmental aspects of improving problem solving and transfer is recommended. Is this a skill that students develop as they age? Are there incremental increases as the student ages? A cross grade comparison would be of interest.

Recognizing the implications described in the Campione and colleagues' study (1995), it would be of interest to use this framework to study the impact of the classroom culture on problem solving and transfer. To what degree is student problem solving and transfer dependent on the teacher, or the problem situations, or the specific teaching methods, or the levels of questioning?

In conclusion, continued study on this critical topic is imperative. The findings of the current study indicate the challenges of teaching students to problem solve and to transfer knowledge and skills. However, preparing today's students to be the problem solvers of tomorrow is not only a worthy goal. Our future as a nation is dependent upon our success.

APPENDIX

Appendix

Interview Questions

The following questions will be asked in the interviews with the teachers, students and parents. These questions will focus on strategies that facilitate problem solving transfer as well as examples of problem solving and problem solving transfer within and outside the classroom.

Teacher Interview

1. How would you describe the Montessori model of learning?

2. How is new information presented to the students?

3. How long do students work on specific learning activities? Please describe the process.

4. How do you know students are learning?

5. Please describe situation when students have used previous knowledge to understand something new?

Student Interview

1. What is learning like in a Montessori classroom?

2. How do you learn new information in class?

3. Describe some of the works you have been doing recently. How long have you been working on them?

4. How do you know you have learned something new?

5. Can you think of a time when already knowing something has helped you to learn something new?

Parent Interview

1. How would you describe the Montessori model of learning?

2. I understand your son/daughter has been studying ____________in class recently. Please describe any situations or conversations when your child has related the information they learned in class to something outside of the classroom.

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