The Effect of Forward-Reaching and Backward-Reaching Transfer Instruction on Second Graders' Problem-Solving Ability

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Abstract

The purpose of this study was to determine whether direct instruction on forward and backward-reaching transfer would improve second grade students' ability to apply past learning to solve new problems and deduce applications to future problems. The study was quasi-experimental, and used random selection to assign ten second grade students each to the treatment and control groups. Both groups received 30 minutes of general mathematics instruction. The treatment group received an additional 30 minutes of transfer training for one week. All 20 students in the treatment and control group completed one "Problem of the Day" exercise each day for two weeks. Daily post-problem questionnaires which asked students to connect the problem with prior knowledge or a future problem were given to both the treatment and the control groups and responses on them were compared to assess students' utilization of transfer training. A pre/posttest was utilized to determine the treatment group's understanding of forward and backward-reaching transfer. Comparison of the total Problem of the Day solution scores between both groups revealed no significant difference in performance. The mean differences on five variables, compared between the treatment and control group, determined no significant difference in participants' ability to apply transfer strategies. Although there were no significant findings, observations and other research suggest that teaching transfer strategies may improve problem-solving in second grade students. Educational implications and suggestions for future research are discussed.

CHAPTER I

INTRODUCTION

Overview

Education is in yet another transitional period with the adoption by Maryland of the Common Core Curriculum. The new Common Core State Standards focus on building a conceptual understanding of core concepts from an early age, providing students ample opportunity and time to develop the skills and concepts reflected through the Common Core. The Common Core State Standards reduce the number of skills and concepts to be presented at each grade level, but require deeper understanding of the skills and concepts represented within the standards and greater rigor in their presentation (Common Core State Standards Initiative, 2012).

Problem-solving in mathematics is at the forefront of the Common Core State Standards, which use the National Council of Teachers of Mathematics process standards of problem-solving, reasoning, communication, representation, and connections (Common Core State Standards Initiative, 2012). Problem-solving can be a daunting task for many young learners and teachers, as curricular goals change from emphasis on rote learning to developing abstract thinking. Rote facts and operations are simple and concrete, whereas problem-solving requires learners to comprehend the question, connect given data to prior learning, and devise a plan utilizing a variety of mathematical skills to solve problems. Students may become frustrated or feel they cannot solve the problems presented.

As a second grade math teacher, this researcher has found that many young learners faced with a problem-solving activity are not utilizing the strategies and skills that they possess from prior learning to find a solution. Often, they appear unaware that they already possess all of the tools needed to solve a problem and can apply past methods to this novel situation. Building mathematical awareness, insight, and confidence is vital if students are to develop into independent problem-solvers. Based on her observations of her students' responses to novel problem-solving situations, the researcher desired to learn more about what might help students apply past learning to solve novel problems and identify applications for future problems.

Statement of Problem

The purpose of this study was to determine whether explicit mathematics instruction on forward-reaching and backward-reaching transfer impacts students' ability to apply past learning to solve novel problems and deduce applications for future problems.

Hypotheses

This study tests two null hypotheses. First, it was hypothesized that there would be no significant difference in the problem-solving accuracy of second grade students who received direct instruction about forward-reaching and backward-reaching transfer strategies compared to that of students who were not instructed in the transfer strategies.

ho1:

mean problem-solving accuracy of trained students =

mean problem-solving accuracy of untrained students

Second, it was hypothesized that there would be no significant difference in the mean daily ratings of the of students' ability to apply forward-reaching and backward-reaching transfer strategies between the treatment group, which received direct instruction about forward-reaching and backward-reaching transfer strategies and the control group, which did not.

ho2:

mean daily ability to apply transfer training of the trained students =

mean daily ability to apply transfer training of the untrained students

Operational Definitions

A variety of terms are used to define the independent and dependent variables of this study.

- *Problem-solving:* According to NCTM, "*Problem-solving* means engaging in a task for which the solution method is not known in advance. In order to find a solution, students must draw on their knowledge, and through this process, they will often develop new mathematical understandings" (NCTM, 2000, p. 52). Students' ability to problem-solve was measured through the dependent variable of a Problem of the Day.
- *Problem of the Day (POD):* a problem-solving activity, usually in the form of a word-problem that may utilize multiple mathematical concepts and can be solved using more than one solution method. (See Appendix A for examples).
- *Transfer:* the ability to apply previously learned skills and knowledge to a novel situation. Two types of transfer were taught to the students in the treatment group: forward-reaching and backward-reaching transfer. Fuchs and his colleagues defined these high-road transfers in their 2002 study.
  - *Forward-reaching transfer:* occurs when learners think about other situations where the principle might apply during the initial learning task.
  - *Backward-reaching transfer:* occurs when the learner approaches a novel problem and searches for connections to previous tasks.
- *Problem-solving rules:* the steps a learner should take to solve a problem-solving task. These steps include (a) reading the problem and reflecting on what the problem is asking, (b) devising a plan, (c) executing the plan, and (d) checking and reflecting on the solution method.

CHAPTER II

REVIEW OF LITERATURE

This literature review examines how educators can help students transfer meaningful knowledge from one problem-solving situation to another to create a strong foundation of mathematical understanding. Section one defines the phenomenon of transfer, the many types of transfer, and its importance in learning mathematics. Section two discusses factors affecting transfer. Section three addresses ways to teach for transfer of learning to occur.

Mathematical understanding is a web of complex and interconnected knowledge. Just like a hammock's strength comes from the intertwined knots of rope, each relying on the other to hold the weight, one's mathematical understanding is strengthened by the web of connections he/she creates when discovering how ideas are related to one another (Lambdin, 2003). Even if a knot in the web of the hammock unravels, the structure still can bear weight. However, if the hammock was created using single, unconnected strands of rope strung from one point to another with no interweaving, a broken strand could weaken the structure (Lambdin, 2003). Mathematics teachers help students build their own hammock of mathematical knowledge that can bear the weight of any problem-solving challenge. Unfortunately, young students often are unable to recognize the conceptual connections between problem-solving situations and how knowledge can be applied to a variety of situations, leaving them with single, unconnected strands of knowledge (Parker, 2009). Teachers face the challenge of helping students transfer meaningful knowledge from one problem-solving situation to another to weave a strong web of understanding. The puzzling question of transfer and how it can be obtained has been "simmering beneath the surface of educational inquiry" (Perkins & Salomon, 1989, p.114) for many years.

Defining Transfer

Psychologists, educators, and scientists have been debating the phenomenon of transfer for over 100 years, and a clear definition of transfer of learning is still in question (Perkins & Salomon, 1989; Barnett & Ceci, 2002). Many critics argue that mere learning of rote facts or dates that are repeated by students on a test, or the solving of a problem after repeated practice with a the same solution method on contextually similar problems does not demonstrate meaningful transfer (Transfer of Learning, 2004). A general consensus among researchers identifies transfer as the ability to apply previously learned skills and knowledge to a novel situation (Barnett & Ceci, 2002). However, according to Perkins and Salomon (1989), creating a concrete separation between learning and transfer is difficult because all learning involves the transfer of knowledge on a least a trivial level. Understanding the many dimensions of transfer is the key to promoting the most meaningful transfer in and out of the classroom (Barnett & Ceci, 2002).

Transfer can occur on two different levels, low-road transfer and high-road transfer. Low-road transfer is the automatic, quick, and even spontaneous application of practiced skills, without reflecting on prior knowledge (Perkins & Salomon, 1989). For example, a learner may automatically transfer his/her ability to count on the number line to counting on the hundreds chart. Moving from the number line to hundreds chart took little thought and reflection because the two counting manipulatives utilize the same continuous pattern of numbers, simply laid out in a different way. Problem-solving tasks are considered a form of high-road transfer; requiring a learner to search for abstract connections between novel and familiar problems (Fuchs, Fuchs, Hamlett, & Appleton, 2002). High-road transfer is rendered when a mindful abstraction, or a thoughtful identification of related schema or principles, takes place through either forward-reaching transfer or backward-reaching transfer (Perkins & Salomon, 1989). Forward-reaching transfer occurs when learners think about other situations where the principle might apply during the initial learning task (Fuchs et al., 2002). For example, when a child is learning how to make a chart, he/she may think about how a chart can be used to solve a variety of problems. Backward-reaching transfer, on the other hand, occurs when the learner approaches a novel problem and searches for connections or abstractions to previous tasks (Fuchs et al., 2002). For example, a learner may utilize skip-counting learned and executed in a previous task to add a set of coins. Educators and learners must be mindful that low-road transfer does not impede meaningful high-road transfer with learners applying a familiar routine without looking deeper into the problem (Perkins & Salomon, 1989).

Transfer also can be measured within two contexts; near and far (Transfer of Learning, 2004). Applying learning to a task that is closely related to the original learning task and often within the same domain is considered near transfer, whereas applying learning to a task that is quite different and often across domains is considered far-transfer. Measuring the distance of transfer, as near or far, is difficult to formalize because of individual perceptions of similarity between tasks (Transfer of Learning, 2004; Perkins & Salomon, 1989). Barnett and Ceci (2002) developed a taxonomy of far transfer (Figure 1) with the belief that far transfer is the vital puzzle piece to the question of how to train learners for transfer to ensure that learning created in school will be applied over time and contexts. This taxonomy can be a useful tool for understanding the many dimensions of transfer, including what is being transferred (the content) and when and where it is transferred (the context), as well as measuring the distance of transfer along a continuum of near and far (Barnett & Ceci, 2002, p. 624).

A Content: What transferred			
Learned skill	Procedure	Representation	Principle or heuristic
Performance change	Speed	Accuracy	Approach
Memory demands	Execute only	Recognize and execute	Recall, recognize, and execute

B Context: When and where transferred from and to					
	Near ←				→ **Far**
Knowledge domain	Mouse vs. rat	Biology vs. botany	Biology vs. economics	Science vs. history	Science vs. art
Physical context	Same room at school	Different room at school	School vs. research lab	School vs. home	School vs. the beach
Temporal context	Same session	Next day	Weeks later	Months later	Years later
Functional context	Both clearly academic	Both academic but one nonevaluative	Academic vs. filling in tax forms	Academic vs. informal questionnaire	Academic vs. at play
Social context	Both individual	Individual vs. pair	Individual vs. small group	Individual vs. large group	Individual vs. society
Modality	Both written, same format	Both written, multiple choice vs. essay	Book learning vs. oral exam	Lecture vs. wine tasting	Lecture vs. wood carving

Figure 1. Taxonomy for far transfer.

Factors Affecting Transfer

Much research has explored the possible factors that affect a learner's ability to transfer learning and strategies within and across domains. Fuchs et al. (2002) identify three essential components of successful transfer: a broad schema, mastering of problem-solving rules, and an awareness of the connections between previously solved problems and novel problems. Other factors, such as learner disposition, classroom culture, nonverbal processing, and instructional method, discussed below, also have been identified as contributing influences in transfer success.

The research of Judd in 1908, father of the General Principle Model of transfer, suggested that transfer occurs when a learner understands "the abstract general principle(s) underlying phenomena that then can be applied to situations that do not possess obvious identical elements but that have the same or similar underlying principle" (Transfer of Learning, 2004, p. 5). A broad schema helps promote awareness of these underlying connected principles. A schema is a generalized plan for solving a problem, which can be used to organize underlying structures of problem types (Fuchs et al., 2002; Powell, 2011). For example, when a learner can identify a problem type, then a schema, such as a diagram, can be applied to solve the problem (Powell, 2011). The broader the schema, the more likely a learner will recognize connections between familiar and novel problems, and know when and how to apply learned solution methods (Fuchs, Fuchs, Finelli, Courey, & Hamlett, 2004). To build a broad schema, problem-solving instruction should foster conceptual and content-specific knowledge (Rittle-Johnson, 2006).

As defined by Rittle-Johnson (2006), conceptual knowledge is "the understanding of principles governing a domain and the interrelations between units of knowledge in a domain" (p. 3). In the metaphor of a learner's hammock of mathematical knowledge described above, the greater the conceptual understanding, the stronger the link of rope between the knots of mathematical knowledge. Reflective practice through self-explanation, the observation of a peer's transfer process, and the explanation of connections between familiar and novel problems also were identified by Rittle-Johnson as key components of successful transfer. Many studies also have expressed the importance of learners obtaining adequate content-specific, or declarative knowledge to tackle a problem-solving activity (Transfer of Learning, 2004). Insufficient learning of content, insufficient time encoding original learning, and inappropriate encoding of content have been identified as variables of failure to transfer (Transfer of Learning, 2004). Learners need to possess significant and appropriate background knowledge to complete a problem-solving task. Insufficient knowledge can lead to negative transfer, the retrieval or application of inappropriate schema (Transfer of Learning, 2004). Instruction should supply students with adequate time and practice of mathematical content, and meaningful content should be encoded, not just rote facts, to ensure that positive transfer takes place (Transfer of Learning, 2004).

Fuchs et al. (2002) also identified mastering of problem-solving rules as a vital indicator of successful transfer. Less working memory, another influence of transfer, is devoted to solution details when a learner has mastered problem-solving rules. Instead, learners focus their cognitive resources on identifying connections between problems and developing a solution plan (Fuchs et al., 2002). Harris and Pressley (2006) identify problem-solving rules executed by good problem solvers to include: (a) reading the problem in entirety and reflecting on the numbers and relationships presented, (b) devising a plan using prior knowledge and looking for similarities between previous problems and the current problem to determine if solution methods can be applied to this case, (c) executing the plan, and (d) checking and reflecting on the solution method, including trying another possible solution method and identifying key elements of the problem and a plan that could be used on future similar problems. Understanding the general rules of problem-solving will give learners a guide to follow when encountering a novel problem.

The third essential component of successful transfer identified by Fuchs et al. (2002) is an awareness of the connections between previously solved problems and novel problems, which can be fostered by building metacognition in learners. Learners with a rich metacognitive understanding know the value of cognitive strategies, including how to identify when and where learned solution methods can be applied (Harris & Pressley, 2006). Upon analyzing 100 studies of transfer strategies, Belmont, Butterfied, and Ferretti (1982) concluded that learners were more likely to use transfer strategies if opportunities were presented to practice when and where strategies worked, as well as identifying benefits produced through these strategies and their application to new situations (Harris & Pressley, 2006). Metacognition also includes understanding what transfer is and how it works, and developing a disposition of thinking and encoding learning into transfer schemas (Transfer of Learning, 2004). Promoting transfer-like thinking during problem-solving can help learners independently activate forward-reaching and backward-reaching transfer methods to make connections between problems (Fuchs et al., 2004).

Learner disposition also has been identified by many researchers as an influential factor in the transfer process (Transfer of Learning, 2004; Furinghetti & Morselli, 2009). A learner's attitude towards mathematics and learning, and perception of their own mathematical abilities can either promote or hinder transfer of knowledge. Searching for connections between problems requires patience, perseverance, and deep thinking, which can be a frustrating process for many young learners. Studies have suggested that cognitive and affective factors are intertwined in the mathematical process (Furinghetti & Morselli, 2009). Through a case study analysis of two mathematics students working through the problem-solving process, Furinghetti and Morselli (2009) discovered affective factors that can hinder or help the cognitive process may include, self-confidence, feelings of inadequacy, ability to manage emotions during the mathematical process, and beliefs of the purpose of mathematics. They concluded that educators and students need to reflect on their habits of mind during the process to understand that "every unsuccessful problem solver is unsuccessful in his or her own way" (Furinghetti & Morselli, 2009, p. 87). Transfer is more probable if students are taught to monitor their performance as they work through a problem and taught how to manage their emotions with coping mechanisms in the light of failures (Harris & Pressley, 2006).

Another factor that affects transfer is nonverbal processing, or the working memory and spatial cognition of the learner. Content-specific knowledge and procedural knowledge are stored in long-term memory and only accessed when needed; however, active thinking, such as that employed during the problem-solving and transfer process, takes place in working memory (Harris & Pressley, 2006). During the problem-solving process, long-term memory contents are activated and transferred into working memory, where they are thought about in terms of the current problem-solving task (Harris & Pressley, 2006). Unfortunately, working memory is limited, especially in young learners who can only hold a few items in visual and verbal working memory at a time (Instruction and Cognition, 2005). Therefore, learners have to know how to decipher through a problem to identify only the most important visual and verbal elements (Instruction and Cognition, 2005). If learners can activate their prior knowledge in long-term memory and bring it into their working memory with the most important components of the current problem-solving activity, then they may successfully transfer knowledge to the new problem. While some activation of long-term and working memory is automatic, such as when adding rote facts, other experiences are learner-controlled through deliberate activation of prior knowledge – a characteristic of an effective problem solver (Harris & Pressley, 2006). While educators and learners cannot completely control the expansion of working memory, building broad schemas of organized knowledge can alleviate some of the limitations of working memory (Harris & Pressley, 2006). Educators can help students recognize how problems are alike, so problem characteristics can be organized into larger concepts, such as problem type and structure, to prevent memory overload; as well as provide sufficient time for encoding content into long-term memory to ensure that the content can be accessed when needed and utilized in the transfer process (Transfer of Learning, 2004).

An additional factor that affects transfer is the structure and culture of the learning environment. Learning and its transfer currently are being linked to the context in which the learning takes place, not just to an innate quality of the learner (Transfer of Learning, 2004). The learning context does not include just the classroom setting, but the method of instruction, and the social norms that are established by the teacher (Transfer of Learning, 2004). Effective problem-solving classrooms that promote transfer establish social norms of sense-making, sharing of ideas, reflection, and evaluation of mathematical ideas using reasoning (Teaching of Mathematics, 2004). According to the constructivist theory, problem-solving tasks should utilize prior knowledge, while also challenging current understandings to create richer conceptual knowledge (Teaching of Mathematics, 2004). In a study of how learning contexts facilitate transfer, Borkowski and Muthukrishna (1995) concluded that a classroom environment and culture that promote conceptual and metacognitive understanding possibly can change mathematical beliefs and motivation, a key factor of transfer. When deep learning and understanding are the goal of a classroom which is built in the transfer process and not portrayal of one's abilities only, children are more likely to value and use their schemas (Borkowski & Muthukrishna, 1995).

Teaching for Transfer

The question of which learning contexts best promote transfer of prior knowledge to novel problem-solving situations has been in question for years. Numerous studies have been conducted to identify the best instructional methods for building the transfer process in older students; however, little research has been conducted with younger primary-aged students. This section discusses three significant studies conducted with young children to determine the best possible instructional method to promote mathematical transfer.

Schema-based transfer instruction (SBTI) has evolved from several research studies conducted by Fuchs and his colleagues (Fuchs et al., 2002; Fuchs et al., 2004) to improve mathematical problem-solving in primary grade children. SBTI, derived from the schema construction theory, utilizes the specific teaching of transfer features to build broad problem-solving schemas by emphasizing how superficial features can make a problem seem different, when in reality the problem structure and solution do not change (Fuchs et al., 2002). The problem-solving treatment utilized in these studies included two components, (a) teaching problem solutions for different types of problem structures, focusing on the underlying concepts of the problem, not the superficial features and (b) explicit instruction in transfer to affect mindful abstraction. The abstractions that are mindfully pulled from long-term memory should be an understood schema, not just an automatic learned fact or formula, in order for positive transfer to occur (Perkins & Salomon, 1989). The transfer features taught included different format, different vocabulary, different question, irrelevant information, combining problem types, and mixing superficial features (Fuchs et al., 2002; Fuchs et al., 2004). Study participants also received direct instruction on the meaning of transfer, what transfer looks like, and when and where transfer features can be applied using worked examples (Fuchs et al., 2004). Participants were given time to practice applying solution methods to problems with varying transfer features, and were cued to look for transfer features in novel problems to make connections between familiar problem types (Fuchs et al., 2004).

The explicit transfer instruction was based on Perkin and Salomon's (1989) suggestion of teaching learners to transfer through recognition of opportunities for forward-reaching and backward-reaching transfer (Fuchs et al., 2002). Fuchs et al. (2004) found that SBTI groups improved more on near-transfer distance problems and far-transfer distance problems within the mathematics domain than the control group that received the general mathematics curriculum instruction. Far-transfer problems for the experimental group were structured in a significantly different manner than the instructional tasks. It was concluded that instruction of various challenging transfer features to broaden schemas for making connections between problems enhances performance on real-life, challenging problem-solving activities and creates meaningful learning (Fuchs et al., 2004). Furthermore, a learner's prior competence with problem-solving proved to not be a detrimental factor in his/her success, indicating that the SBTI approach could be utilized with an array of ability levels in a whole group setting (Fuchs et al., 2004). Fuchs et al. (2004) suggests the need for additional exploration to identify ways to fuse SBTI with other instructional approaches to enhance students' ability to solve real-world problems.

Critics of direct instruction strategies argue that only spontaneous transfer, without assistance and cueing, constitutes transfer (Transfer of Learning, 2004). According to Perkins and Salomon (1989), active learning where abstractions are rendered independently produces farther transfer than passive learning where connections between problems are taught directly to students. This may be due to the learner's ability to choose the problem-solving direction and schema to activate, whereas passive instruction involves the elicit abstraction chosen by the teacher (Perkins & Salomon, 1989). Borkowski and Muthukrishna (1995) studied the role of instructional method in the attainment and transfer of a mathematical strategy in third graders. Three instructional contexts were explored: direct strategy instruction, guided discovery, and direct strategy instruction with guided discovery. In the direct strategy instruction group, students were taught a strategy to target a specific schema, emphasizing how to organize knowledge and make connections to prior knowledge (Borkowski & Muthukrishna, 1995). Modeling and extensive practice of the strategy included opportunities for students to discover when, how, and where the strategy could be applied to novel situations (Borkowski & Muthukrishna, 1995). The guided discovery context utilized a constructivist approach with partners working to solve problems and the teacher serving as guide in provoking meaningful thinking (Borkowski & Muthukrishna, 1995). Each guided discovery session ended with a whole class discussion of the problem, where students were encouraged to explain, justify, and even challenge their thinking and the processes of their classmates (Borkowski & Muthukrishna, 1995). The direct strategy instruction with guided discovery group was taught the same schema as the direct strategy instruction group and how it could be used, but was then encouraged to work in groups to determine how to the strategy could be applied to other problems (Borkowski & Muthukrishna, 1995).

On both the immediate posttest and long-term test, the discovery learning groups outperformed the direct instruction groups on far-transfer measures. Far-transfer was defined as problems presented in a different form than instructional problems (Borkowski & Muthukrishna, 1995). Results from the study indicated that the discovery learning group made greater use of deep processing strategies than the direct instruction and combined groups; and both the discovery learning group and combined group reported placing more importance on understanding and collaborating in the problem-solving practice (Borkowski & Muthukrishna, 1995). Borkowski and Muthukrishna (1995) suggest that these results demonstrate the positive effects of discovery learning on the transfer process. Because students were forced to justify their thinking in the discovery learning context, it can be concluded that they utilized deeper processing levels than the direct instruction group and were able to make connections between prior and new problems.

The more recent work of Rittle-Johnson (2006) explored whether the use of self-explanation within the context of direction instruction or invention promotes more long-term transfer success in third through fifth grade students. The instruction group received direct instruction of a strategy; whereas the invention group received no direct instruction, but was prompted by the teacher to think of new ways to solve the problem and received feedback on their answers (Rittle-Johnson, 2006). This was the extent of the no-explanation manipulation groups. Rittle-Johnson explains that in the self-explanation manipulation groups, after solving each problem and being shown the correct answer, two additional answers from children of another school were shown to the study participants, one correct and one incorrect (Rittle-Johnson, 2006). The students in the manipulation groups were asked to explain how the other children found their answer and to explain why it was correct or incorrect. An immediate verbal and written posttest of two problems was given after the intervention that required students to explain their solution methods, and a delayed posttest was completed two weeks later.

Results from this study indicate that self-explanation promotes greater maintenance of learning and transfer over time, in both direct instruction and invention (Rittle-Johnson, 2006). Self-explanation assists in enhancing procedural knowledge, adapting procedures to solve novel transfer problems, and retaining procedural knowledge over time; whereas no self-explanation leads to the use of old and incorrect procedures (negative transfer) (Rittle-Johnson, 2006). Futhermore, Rittle-Johnson (2006) suggests that self-explanation can broaden schema and metacognitive understanding of application to a variety of novel problems. Study participants in the self-explanation group were able to adapt procedures to solve new transfer problems that required a deeper understanding of the procedure components than just initiating the rote procedure. In regards to the type of instruction, direct or invention, Rittle-Johnson attests that neither instructional context impacts transfer, with both groups scoring almost equally on transfer problems. Instead, the key to transfer may be active processing through self-explanation. Rittle-Johnson predicts that “direct instruction on a correct procedure and conceptual explanation for the procedure would lead to the greatest learning and transfer if students were also prompted to self-explain” (p. 13).

These studies have explored a variety of instructional methods, both conventional and constructivist, to discover how transfer of mathematical knowledge can be enhanced and extended to novel problem-solving situations. The researchers attempted to determine which method is better at promoting transfer in problem-solving activities. These researchers all agree that this question and many others about the phenomenon of transfer require further study to improve the quality of problem-solving instruction and learning in the classroom (Borkowski & Muthukrishna, 1995; Fuchs et. al., 2004; Rittle-Johnson, 2006).

CHAPTER III

METHODS

The purpose of this study was to determine whether explicit mathematics instruction on forward-reaching and backward-reaching transfer impacts students' ability to apply past learning to solve novel mathematics problems and deduce applications for future problems. The researcher desired to learn more about how to help her second grade learners who were faced with a problem-solving activity utilize the strategies and skills that they possessed from prior learning to find a solution.

Design

A quasi-experimental design was used in this study. The study included two groups of students, a treatment group and a control group. The study was designed to compare the problem-solving skills of the two groups. The study examined the effect of training about forward-reaching and backward-reaching transfer on student success in novel problem-solving and students' ability to apply past and prior knowledge when solving problems. In this study, the independent variable was the transfer training, and the dependent variable was student success on problem-solving tasks and their ability to apply and explain the use of transfer training.

The study took place over a three week period in a second grade math class. During the first week, the treatment group received one week of transfer and problem-solving training in addition to the general mathematics curriculum, while the control group continued to receive only the general mathematics curriculum. In the two weeks that followed, both the treatment and the control group received problem-solving tasks through a Problem of the Day (POD) to assess problem-solving accuracy. A pretest and posttest were administered to determine treatment group participants' understanding of the transfer training. Daily post-problem questionnaires which asked students to connect the POD with prior knowledge or a future problem were given to both the treatment and the control groups to assess students' utilization of transfer training.

Participants

The study took place at a public elementary school in a suburban Maryland community. The participant sample was composed of 20 second-grade math students of mixed mathematical ability and gender. These students were previously taught the general mathematics curriculum designed by Baltimore County Public Schools. This class also received instruction based upon the Primary Achievement and Curriculum Enrichment (PACE) mathematics lessons, an extension and enrichment program offered to all students to provide opportunities for higher-level thinking. Students of all ability levels can attempt PACE lessons and activities.

The class of 20 students was randomly divided into two groups, the treatment and control group, using a random selection table of numbers. The treatment group was composed of ten students, six girls and four boys. The remaining ten students in the class, eight girls and two boys, comprised the control group. Review of the literature suggests that this is one of the youngest grade-levels studied in the field of transfer.

Instruments

Multiple instruments developed by the researcher were used to conduct this study. First, the researcher developed the transfer training tools that were utilized with the treatment group during the first week of the study. These tools consisted of a problem-solving rules bookmark for each student, four completed examples of problem-solving tasks, and four practice PODs. Examples are found in Appendix A.

A two part worksheet, consisting of a daily POD and post-problem questionnaire, was utilized during the treatment phase of this study (See Appendix B). The POD questions were created by the researcher using components of the Scotts Foresman reading series from the Baltimore County issued curriculum, The Common Core State Standards Mathematics Curriculum, the website www.mathbuddyonline.com, and from the researcher's own invention. Each POD consisted of a novel problem-solving task that the students had not previously seen or been taught in school. Each problem-solving task utilized and built upon previously taught content or mathematics from kindergarten, first, or second grade. The problems used a statement and question format, and usually could be solved in more than one way.

The post-problem questionnaire, located at the bottom of the worksheet, was completed by all students in both the treatment and control group following their completion of the POD. The questionnaire consisted of four questions to assess utilization of both transfer strategies. To assess backward-reaching transfer the following questions were posed: (1) Did you use prior knowledge to solve the Problem of the Day? (1b) What prior knowledge helped you solve it or how is it like something you have done in the past? To assess forward-reaching transfer the following questions were posed: (2) Could solving this problem help you solve a different problem in the future? (2b) Give an example of how you could solve a new problem this way.

A rubric generated by the researcher was used to score the solution accuracy of the POD question, and the quality of responses on the transfer questionnaire (See Appendix C). The rubric assessed the level of performance as (a) Not Evident, zero points, (b) Emerging, one point, (c) Proficient, two points, or (d) Exemplary, three points.

The rubric was broken into three categories, The Problem of the Day, Backward-Reaching Transfer, and Forward-Reaching Transfer. POD solutions were marked correct or incorrect, but the representation of the solution method was awarded a performance level on the rubric with a total possible score range of zero to three. Students were awarded a performance level in each transfer category for connections and communication (parts 1 and 1b and 2 and 2b), with a total possible score of 12 points.

An additional instrument was created for the treatment group only. A simple pre- and post intervention questionnaire was used to assess the treatment group's understanding of backward-reaching and forward-reaching transfer (See Appendix D). The questionnaire was given to the treatment students at the end of the transfer training in Week One, and then again upon completion of the study in Week Three. The questionnaire consisted of two simple questions: (1) What is backward-reaching transfer? (2) What is forward-reaching transfer? The same performance level scale of (a) Not Evident, (b) Emerging, (c) Proficient, or (d) Exemplary, was used on a rubric to assess student ability to communicate an understanding of both transfer strategies (See Appendix E). A total of 12 points could be earned, three points each for the forward-reaching transfer definition and example and three points each for the backward-reaching transfer definition and example.

Procedure

The second grade math class was randomly divided into two groups. The treatment group received 30 minutes of training each day for one week from the researcher on backward-reaching and forward-reaching transfer. Day One of the training week consisted of problem-solving rules instruction. The lesson began with a guided discussion about the steps a good problem-solver takes when solving a new problem. This discussion led to the development of a student-created bookmark featuring five problem-solving rules identified by the students. These rules include: (a) Read (b) Reflect and Look for Clues (c) Plan (d) Solve, (e) Check. The researcher then posed a problem for the students to solve using their Problem-Solving Rules

Bookmark as a reference. Students worked in partners to solve the problem and then shared their solutions and method during a whole-group discussion.

The remainder of the training week consisted of two days focused on backward-reaching transfer and two days on forward-reaching transfer. Day One of backward-reaching transfer consisted of the three steps described below.

1. A beginning dialogue about what students think about as they solve a problem was initiated. Questions such as, “Do you think about something you have done before? Do you relate a new problem to a past problem? Do you see patterns or familiar math ideas that we have studied?” were asked to the students to spark their thinking in the path of using prior knowledge.
2. In step two, students were shown a completed example of a problem. The group discussed how the problem was solved and what past skills or math content were used to solve the problem. Backward-reaching transfer was defined.
3. Finally, students were given a problem to solve with a teacher-assigned partner. They were reminded to think about what the problem was asking, to identify math ideas within the problem that they already knew, and to make connections to ways they have solved problems with similar components in the past. Upon completion of the problem, each pair shared their solution method and thought process.

Day Two of backward-reaching transfer repeated Steps 2 and 3 with new problems.

The final two days of the week were devoted to forward-reaching transfer training. Day One of forward-reaching transfer consisted of three steps:

1. A beginning dialogue was initiated to discuss whether students had ever thought about how they could solve a future problem using a method that they have used before.

Questions about the previous day's problem were used to encourage students to think about forward-reaching transfer. Questions included "How could we use yesterday's solution method in the future? What elements might a problem have to contain to use the same solution method?"

2. In step two of the process, students were shown one of the completed solution methods from a prior problem and a new problem that could use the same method to solve. The group discussed the similarities and differences between the two problems and worked together to solve the new problem using the known method. Forward-reaching transfer was defined.
3. Finally, students were given a completed problem. The group discussed how the problem was solved. Students worked in teacher-assigned partners to create and solve a new problem that could use the same solution method. Each partner group shared their problem with the entire treatment group and discussed their solution method.

Day Two of forward-reaching transfer repeated Steps two and three with new problems.

The week culminated in a review discussion of how students could use backward-reaching and forward-reaching transfer to problem solve. The definitions for each transfer strategy were added to the back of the students' problem-solving rules bookmark. Finally, the treatment group received a pretest questionnaire to complete regarding their understanding of the two transfer strategies (See Appendix D). The questionnaire was not discussed as a group.

For the next two weeks, the treatment and control group continued to receive 30 minutes of instruction in the general math curriculum for the first half of each math period. The remaining 30 minutes of class were devoted to a POD. Both the treatment and the control group completed a POD. Each child was given a POD worksheet consisting of problem at the top of the page, room to show their work in the middle of the page, and a questionnaire at the bottom of the page. The students were given 30 minutes to solve the problem. The only time the researcher assisted the students in the problem-solving task was to read the problem to them, since reading comprehension was not the focus of this study. The treatment group was allowed to use their problem-solving rules bookmarks during the POD activity.

In order to avoid influencing students' responses or inadvertently provide the intervention (explicit training regarding backward and forward transfer) to the control group, the PODs were collected and saved to be reviewed with the whole group at the conclusion of the two week post-training intervention period. At that time, the control group was also taught about the concepts of backward and forward transfer and encouraged to apply them to problem-solving situations. After this two week period, the treatment group was re-administered the questionnaire to assess their understanding of the two transfer strategies. The posttest questionnaire is included in Appendix D.

CHAPTER IV

RESULTS

The purpose of this study was to determine whether explicit mathematics instruction on forward-reaching and backward-reaching transfer affects students' ability to apply past learning to solve novel mathematics problems and deduce applications for future problems. The initial null hypothesis was tested by comparing the total Problem of the Day (POD) solution scores of students in the treatment group, who received training in transfer strategies, to those of students in the control group, who did not. The POD solution scores for the ten days of the intervention, which ranged from zero to one each day, were summed to yield the total for comparison. Descriptive statistics of the total POD scores for the sample and for both groups follow in Table 1. These results suggest that there was a fairly wide range of scores in both groups, from one to eight for each, with slightly more variation in the control group's performance.

Table 1

Descriptive Statistics for Total POD Solutions by Group and for the Entire Sample

Group	N	Mean	Std. Deviation	Range
Treatment	10	4.6	1.955	1-8
Control	10	4.3	2.263	1-8
Entire Sample	20	4.45	2.064	1-8

A T-test of Independent Samples was conducted to determine whether the difference in the two groups' mean total POD Solution scores was statistically significant. Results comparing the treatment group mean of 4.6 to the control group's mean of 4.3 follow in Table 2.

Table 2

T-test for Equality of Means

Scores	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
TOTAL POD SOLUTION	.317	18	.755	.3	.94575	-1.687	2.287

Equal variances assumed

The results of the T-test indicated that the difference between the treatment and control groups' mean total POD Solution scores was not statistically significant (*t*= .317, mean difference= .3 and $p < .755$) , so null hypothesis one was retained.

Comparison of Ability to Apply Forward and Backward-Reaching Transfer Strategies

Null hypothesis two posited that that there would be no significant difference between the treatment and control groups' ability to apply forward-reaching and backward-reaching transfer strategies. Participants' ability to apply transfer strategies was assessed by collecting and totaling ten daily ratings of their performance on each of the following five variables: representation of the POD, backward and forward-reaching connections to a novel problem, and communication of mathematical thinking and backward and forward-transfer actions. Comparisons then were made of the treatment and control groups' ratings of their performance on each of those five daily tasks. Descriptive statistics were computed and are presented in Table 3.

Table 3

Descriptive Statistics of Total Daily Application Scores for the Treatment and Control Groups

Total Score/Application	**Group (n=10 each)**	**Mean**	**s.d.**	**Range**
Representation	Treatment	14.9	4.332	11-25
	Control	13.1	3.381	9-20
Backward Connections	Treatment	12.1	4.748	4-19
	Control	10.1	3.178	5-14
Backward Communication	Treatment	9.7	4.165	2-16
	Control	7.8	2.860	3-12
Forward Connections	Treatment	9.4	5.358	1-21
	Control	6.3	3.234	1-11
Forward Communication	Treatment	4.5	6.884	0-22
	Control	2.7	3.020	0-10

Results of the T-tests presented in Table 4 list and compare the mean differences for the groups on each of these five variables. The T-test results indicated that none of the five total scores differed significantly across the groups. Differences in the two groups' mean totals did not vary much and ranged from 1.8 for the Representation and Forward Communication task total scores to 3.1 for the Forward Connections task total scores. Based on these results, null hypothesis two was retained for all five application tasks.

Table 4

Results of T-Tests for Independent Samples Comparing Treatment and Control Group Means on Five Transfer-Related Tasks

Total Transfer-Related Task Scores	**t**	**df**	**Sig. (2-tailed)**	**Mean Difference**	**Std. Error Difference**	**95% Confidence Interval of the Difference**	
						Lower	**Upper**
Representation	1.036	18	.314	1.8	1.738	-1.851	5.451
Backward Connections	1.107	18	.283	2.0	1.807	-1.796	5.796
Backward Communications	1.189	18	.250	1.9	1.598	-1.456	5.256
Forward Connections	1.566	18	.135	3.1	1.979	-1.058	7.258
Forward Communication	.757	18	.459	1.8	2.377	-3.194	6.794

Gains in Ability to Define and Provide Examples of Transfer for the Treatment Group

Finally, an identical pre- and posttest was given to the treatment group at the completion of the transfer instruction in Week One and at the culmination of the study in Week Three to determine how well participants who received the transfer training were able to define and give examples of backward and forward reaching transfer. A copy of the test is found in Appendix D. Each of the four items on the test was rated from zero to three. Gain scores were calculated by subtracting the pretest scores from the posttest scores. Descriptive statistics of the gains in the ratings from the pre to post interval follow in Table 5.

Table 5

Descriptive Statistics for Gains in Ratings of Definitions and Examples of Transfer

Posttest GAINS	**N**	**Mean Gain**	**Std. Deviation**	**Std. Error Mean**
Backward Reaching Transfer				
Definition	10	.1	.316	.10
Example	10	.5	1.170	.37
Forward Reaching Transfer				
Definition	10	-.1	.994	.31
Example	10	-.1	.738	.23

One-sample T-tests were then run to determine whether any of the gains were statistically significant for any of the four tasks in Table 5. Results follow in Table 6 and indicate that none of the gain scores' magnitudes were statistically significant or different from zero. The mean ratings of the definitions and examples for backward-reaching transfer went up slightly (.1 for definitions and .5 for examples) but the ratings of definitions and examples of forward-reaching transfer actually decreased by .1 point each. However, as noted, none of the gains or decreases were statistically significant.

Table 6

One-Sample T-Test Results Regarding Gains in Ratings of Definitions and Examples of Transfer

	Test Value = 0					
	t	**Df**	**p**	**Mean Difference**	**95% Confidence Interval of the Difference**	
					Lower	**Upper**
Backward Reaching Transfer						
Definition	1.000	9	.343	.1	-.126	.326
Example	1.342	9	.213	.5	-.343	1.343
Forward Reaching Transfer						
Definition	-.318	9	.758	-.1	-.811	.611
Example	-.429	9	.678	-.1	-.628	.428

CHAPTER V

DISCUSSION

This study was conducted to assess the effects of training second grade students to understand and use forward and backward-reaching transfer concepts to solve mathematical problems. The results of this investigation led to retention of the first null hypothesis of the study, which posited that the mean Problem of the Day (POD) solution accuracy for second grade students who received direct instruction in transfer strategies would be statistically equivalent to that of students who did not receive transfer instruction. The second null hypothesis also was retained, as no significant differences were found between the treatment and control groups' ability to apply transfer strategies to novel problem-solving activities. This ability was assessed using five outcomes which reflected the following transfer skills: representation of the problem, forward and backward connections, and forward and backward communications.

Implications

Results of this study indicated there was not a statistically significant difference between the treatment and control groups' ability to apply transfer strategies to accurately solve word problems. This implies that direct instruction in forward-reaching and backward-reaching transfer may have had little or no effect on the overall problem-solving success of the second grade students in this study. However, the researcher observed the problem-solving proficiency and approach change in two of the treatment group participants after participating in the transfer instruction. One high-achieving math student in the treatment group became more vocal during the instructional week's discussions and was able to communicate her connections more accurately as the weeks progressed. She was one of the few students in the treatment and control group who was able to develop an authentic forward-reaching connection in more than one of the PODs and she frequently obtained the maximum score of three on tasks which required her to make backward-reaching connections.

Another student in the treatment group who often exhibited signs of anxiety and low confidence in math seemed to benefit greatly from the transfer strategy instruction as well. Instead of approaching the PODs nervously and depending on teacher support to complete them, she displayed more confidence and completed each POD independently as the intervention progressed. She persevered through the activities, even when she was unsure of the answer. While her solution methods were not always correct, she was able to make a backward-reaching connection with a score of at least one or two each time. She also scored well on the posttest items related to backward transfer, earning the maximum score of three on the posttest definition and a score of two on the example for backward-reaching transfer. This response suggests that she understood the concept of transfer and that she most likely utilized the backward-reaching strategy of accessing prior knowledge to complete the PODs. Although not all of the treatment group participants demonstrated this progress, these observations suggest that teaching the use of backward-reaching transfer may provide higher-achieving students with a method for more clearly communicating their mathematical thinking and build confidence and problem-solving skills in lower-achieving students.

A decrease of .1 point was observed in scores reflecting the ability of students in the treatment group to define and give examples of forward-reaching transfer on the posttest. In contrast, a .1 point increase was observed in scores reflecting students' ability to define backward-reaching transfer and a .5 point increase was observed in their ability to give examples of backward-reaching transfer. These data, in combination with the researcher's observation of low-scoring responses on the daily PODs in the treatment group, demonstrate that forward-reaching transfer was the more difficult transfer strategy for the participants to comprehend and utilize in the problem-solving tasks. Only a limited number of forward-reaching connections met the criteria for scores of two or three. The majority of the treatment group earned scores of only zero or one on forward-reaching connections for each POD.

Based on treatment group participants' responses on the daily PODs and the positive change observed in some students' demeanor and their engagement in the intervention, findings suggest that instruction in backward-reaching transfer, in combination with instruction in problem-solving rules, coping skills and mastery of basic mathematical concepts, may provide second grade students with a beneficial strategy for approaching and solving novel math problems.

Theoretical Consequences

To effectively brainstorm ways mathematical concepts can be used to solve future problems, students first must understand how to use them successfully on current tasks. Previous studies have found that students need a broad schema of foundational skills to be successful in transfer (Fuchs et al., 2004; Powell, 2011; Transfer of Learning, 2004). Observations of the researcher suggest that lower achieving math students were less successful on the PODs, possibly due to a narrow schema with insufficient mastery of prior mathematical concepts utilized in the problems. Futhermore, this study supports previous research on the limited working memory of young learners (Harris & Pressley, 2006; Instruction and Cognition, 2004). Without sufficient time to encode previous learning into working memory and build a strong, broad schema of mathematical strategies and knowledge, young learners may not be able to make the necessary backward-reaching connections between problems.

Therefore, second grade problem-solving instruction should focus on ensuring first that students have mastered the necessary mathematical content and problem-solving rules, and then teach students how to utilize backward-reaching transfer to apply previously learned skills to novel problem-solving situations. Once students have mastered the ability to notice connections between problems, instruction can begin to direct students on the brainstorming path of forward-reaching transfer to develop an understanding of the different types of problems that can be solved using the same math concept. However, it is important to note that even when students in this study successfully solved the POD and scored a two or three on POD representation, they not always were successful in making a forward-reaching connection. Given these observations, forward-reaching transfer may be a concept that is too abstract for many second graders to understand and instruction in its use may not be developmentally appropriate.

Threats to Validity

There were several potential threats to the validity of this study. These threats included the research environment, varying levels of students' mathematical ability and/or reading comprehension skills, the implementation of the study during the general mathematics instructional period, the duration of transfer instruction, and individual student personality traits and work habits.

Research Environment

The study was conducted in the general classroom setting during students' 60-minute math class, with the first 30 minutes devoted to the general mathematics curriculum and the second 30 minutes devoted to the intervention. Due to space and supervision limitations, the researcher conducted the small group transfer lessons on the classroom carpet, while the control group worked at their seats on independent seat work and partner activities. The treatment instruction was interrupted on several occasions by students from the control group requiring teacher support or re-direction to stay on task. This was very distracting for the treatment group, members of which also needed to be reminded to focus on the transfer strategy instruction. Results may have been different had the treatment instruction taken place in a separate room with less distractions.

Lesson Pace and Timing

The interruptions to the treatment instruction in turn affected the pace of the transfer strategy lessons. The lessons were compressed to complete them all in the one week time slot allocated for the instructional part of the intervention. The researcher allotted 30 minutes for each transfer instruction lesson during the first week, but interruptions resulted in students having less time to practice applying the strategies to solve the PODs or to discuss student solution methods and strategy use than was initially planned. The resulting reduction in time for practice and discussion may have negatively impacted student mastery of the transfer strategies.

The fact that the intervention occurred at the end of the regular math instruction period also may have threatened the validity of the study. The general mathematics curriculum was taught for the first 30 minutes of the period each day in the three week study, and the research was conducted in the second half of the mathematics period. In hindsight, had the study taken place in the first 30 minutes of the period instead, the students may have approached the transfer strategy instruction and POD with more enthusiasm and focus. The students tended to appear tired and disinterested by the end of the period which likely diminished their attention to and benefit from the lessons.

Variation in Academic Abilities

Based on observations of the researcher and the students' performance on the PODs and transfer application tasks, it appears possible that variation in the students' mathematical ability level and reading comprehension skills also may have posed threats to the validity of the study. Each POD was formatted as a word problem and was read to the students. Many of the lower achieving reading and math students asked for the problem to be reread several times, had difficulty understanding the problems, and expressed frustration. Word problems are more difficult than rote algorithms and require a level of comprehension necessary to decipher the information provided and determine what the questions are asking in order to solve them. Comprehending the complex PODs was difficult for the lower achieving reading and math students, who also may not have mastered prior mathematical concepts which were necessary to successfully complete the PODs. Research, such as reported by the Encyclopedia of Applied Psychology, has suggested that insufficient learning of content, insufficient time encoding original learning, and inappropriate encoding of content have been identified as variables related to failure to transfer (Transfer of Learning, 2004). Supporting the contention that these basic skills are needed for success at transfer, the higher achieving students, who have mastered more of the second grade math concepts, exhibited greater solution accuracy and more detailed solution representations regardless of their group assignment.

Student Personality Traits and Work Habits

Positive and negative student personality traits were manifested during the study which may have impacted students' performance on the PODs and posed a threat to the validity of the study's conclusions. More successful students in both the treatment and control group displayed determination, curiosity, enthusiasm, and persistence during the POD activities and throughout the entire study, whereas less successful students appeared more easily distracted, frustrated, and less motivated to work through the problems. In some cases, these students did not complete the POD at all and immediately gave up. One student in the treatment group continuously rushed through the problems and wrote the same response for the forward-reaching and backward-reaching connections items for each problem. The researcher also observed a decrease in motivation and determination in several of the participants as the study progressed. Some participants in both the control and treatment groups who initially seemed excited to try something new with the PODs started to lose motivation in the third week, perhaps because they felt the activity was unimportant as it was not graded.

Connections to Previous Studies

Despite lack of statistical substantiation in this study that transfer instruction effectively increases second grade students' problem-solving accuracy, other studies demonstrate the positive effects of such instruction in primary grade students. Fuchs and his colleagues utilized a schema-based transfer instruction (SBTI) approach to improve mathematical problem-solving in primary grade children through the explicit teaching of transfer features and direct instruction on the meaning of transfer, what transfer looks like, and when and where transfer can be applied using worked examples (Fuchs et al., 2004). This current study was designed in a similar fashion and also used worked examples to teach the meaning and method of transfer. However, instead of teaching six different transfer features, as Fuchs et al. (2004) did, this researcher focused on only three transfer features: different question, different format, and different vocabulary. Both studies encouraged participants to practice applying solution methods to problems with varying transfer features and students were cued to look for transfer features in novel problems to make connections to past problems. While this study did not statistically prove that transfer instruction improved student problem-solving efficiency, Fuchs and colleagues found that SBTI groups improved more on near and far-transfer problems than a control group that received the general mathematics curriculum. They concluded that instruction of various challenging transfer features enhances performance on challenging problem-solving activities and creates meaningful learning (Fuchs et al., 2004). Fuchs et al. also determined that the SBTI approach could be utilized with an array of ability levels in a whole group setting, as was done in the current study.

Borkowski and Muthukrishna (1995) also compared the impact of using discovery learning, direct instruction, and combined guided discovery and direct instruction on third graders' use of transfer as a mathematical strategy. In the combined group, students were taught a strategy to apply a specific schema and were shown how the strategy could be applied to novel problems, as well as given opportunities to work with partners to solve novel problems. This researcher utilized a similar approach through the use of completed examples to show students how a math concept or strategy could be used to solve the problem, and gave students an opportunity to work with a partner to use the same concept to solve a novel problem. Each day of the transfer instruction week ended with a group discussion of partner solution methods and inquiries. In Borkwoski and Muthukrishna's study, the discovery learning group was more successful at applying deep processing strategies on transfer measures than the direct instruction and combined groups. It was concluded that discovery learning has positive effects on the transfer process because students were forced to justify and explain their answers, which seemed to result in deeper connections between prior and new problems.

Rittle-Johnson (2006) also explored the use of self-explanation, with students explaining their solution method, within direct instruction and student-centered invention to promote transfer in upper elementary students. The direct instruction group was provided instruction about strategies and the invention group was only prompted to find a new solution method for a problem and then received teacher feedback on their method. The invention group also explored correct and incorrect examples and was asked to tell how the problem was solved and determine whether it was a successful method or not. In the current study, the researcher utilized the same approach as Rittle-Johnson by providing examples and eliciting discussion about partner groups' incorrect solution methods to ensure that the treatment group participants understood how negative-transfer could occur. The current study similarly required students to explain their connections and mathematical thinking on the daily PODs and used a delayed posttest two weeks after the intervention. Results from Rittle-Johnson's study indicated that self-explanation promotes greater maintenance of learning and transfer over time, and a lack of self-explanation can lead to negative transfer of an incorrect strategy or math concept. However, instructional context, direct instruction or invention, were not found to affect success on transfer problems.

Recommendations for Future Research

The researcher has several recommendations for future research in increasing problem-solving success in second grade students. First, the researcher suggests that the transfer strategy training should take place outside of the general classroom and in a small group setting. A small group setting with fewer distractions will help students remain focused and allow the researcher to focus solely on the transfer training instead of managing classroom behaviors and interruptions. In addition, the transfer strategy instruction should be extended to at least two weeks, as opposed to one week. Allotting one week for backward-reaching and one week for forward-reaching training would provide students more time to both master strategies and work through any misconceptions about them. Due to the difficulty grasping and applying the concept of forward-reaching transfer, even for students who scored high in backward-reaching transfer, it would be of interest to determine if students would learn more if they were given extra time to understand and take ownership of the strategy. Due to the students' difficulty, further research appears warranted to determine whether or not forward-reaching transfer instruction is a developmentally appropriate concept to teach second grade students directly.

The researcher also suggests at least doubling the two-week POD study to extend it to four weeks. While problem-solving activities permeate the general math curriculum, this study utilized multi-step and complex PODs that required critical thinking beyond those to which the students were accustomed. Extending the study might provide students with adequate time to become comfortable with the problem-solving and POD routine. As comfort level increases, anxiety and frustration may decrease and ownership of the tasks and confidence in problem-solving may improve. Not only would this help develop and facilitate communication of mathematical thinking, but it also would ensure that a variety of math concepts are explored in the PODs. Some students may have a stronger understanding of certain math concepts than others, and an extended study would allow for a broader array of concepts to be utilized in the word problems. This may provide valuable data for researchers to determine whether transfer strategies are easier or more appropriate for young students to use with particular math concepts.

It also may be beneficial to review the POD with the treatment group after each problem-solving session. Rittle-Johnson (2006) identified reflective practice through self-explanation, observation of a peer's transfer process, and the explanation of connections between familiar and novel problems as key components of successful transfer. This study did not allow the students to discuss their solution methods for the PODs with the class. If a reflective time had been provided, students' transfer ability may have increased as they developed a deeper understanding of the transfer strategies used in the problem-solving process.

Research comparing the effectiveness of transfer instruction on the problem-solving accuracy of students with different reading and math proficiency levels also might help ensure the interventions are used appropriately with students of varying abilities. The question of whether reading comprehension difficulties obstruct the transfer process in problem-solving might be answered through a study comparing the benefits of transfer instruction for students of low-average, average, and high-average reading ability. The noticeable changes in the demeanor of the high-average and low-average math students in the treatment group, also suggested that it might be beneficial to conduct studies to compare the effectiveness of transfer instruction across groups with different math ability levels. Interviewing the students in such studies may provide insight regarding if and how transfer instruction helps them manage their emotions as they navigate through problem-solving and it also may help determine whether transfer-related instruction is developmentally appropriate for second grade students of various ability levels.

Conclusions

In summary, the statistical findings of this study did not indicate that direct transfer strategy instruction significantly affected problem-solving accuracy in second grade math students. However, based on past research and observed changes in student approach to problem-solving in this study, further research is needed to determine whether backward-reaching transfer could be a useful component of problem-solving instruction. More research appears warranted to determine whether or not the methods used so far to teach forward-reaching transfer are developmentally appropriate for young students and whether backward-reaching transfer is beneficial for students of every ability level. In order to make every learner a successful problem solver, students should be equipped with age-appropriate strategies to utilize prior knowledge. If taught in ways which are supported by theory and research and which students can understand, transfer strategies may prove helpful for students to use and apply in math and other content areas.

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Appendix A

Problem-Solving Rules Bookmark Template

Problem-solving Rules	Backward-Reaching Transfer
1.	
2.	
3.	Forward-Reaching Transfer
4.	
5.	

Appendix A

Examples of Problem of the Day (Used in training and treatment)

Example #1

Emily writes a three digit number. The tens digit is five more than three. The hundreds digit is half of the tens digit. The ones digit is two less than tens. What is her number?

Example #2

Ryan, Mike, Jane, and Amy are friends. Ryan is not the tallest, Jane is the shortest. Mike is between Ryan and Amy in height. Who is the tallest?

Example #3

Debbie has 11 oranges and 2 bowls. She does not want more than 5 oranges in each bowl. Does she have enough bowls for all of her oranges? Explain.

Example #4

There are 9 students riding the bus to school. Can they sit in pairs? At the next bus stop, 5 more students get one. Can they sit in pairs now? How many pairs are there?

Example #5

There are 4 dancers in the first row, 8 dancers in the second row, and 12 dancers in the third row. How many dancers are in the fifth row?

Example of a Completed Problem Used in the Transfer Instruction Week

Problem:

Emily writes a three digit number. The tens digit is five more than three. The hundreds digit is half of the tens digit. The ones digit is two less than tens. What is her number?

Completed Solution:

<u>Tens</u> = five more than three
5 + 3 = **8**

H	T	O
4	8	6

<u>Hundreds</u> = half of the tens digit, which is 8
4 + 4 = 8

Emily's number is **486**

<u>Ones</u> = two less than tens
Tens digit is 8, so 8 – 2= **6**

Appendix B

POD Daily Worksheet

Name: ____ Date: ______________________

POD #1

Ryan, Mike, Jane, and Amy are friends. Ryan is not the tallest, Jane is the shortest. Mike is between Ryan and Amy in height. Who is the tallest?

Workspace:

My answer: ________________________

Answer the following questions:

(1) Did you use prior knowledge to solve the Problem of the Day? Yes or No

(1b) What prior knowledge helped you solve it or how is it like something you have done in the past?

____

____

(2) Could solving this problem help you solve a different problem in the future? Yes or No

(2b) Give an example of how you could solve a new problem this way.

____

____

Appendix C

POD Worksheet Rubric

POD Solution: Correct / Incorrect

Task Evaluated	POD	Backward-Reaching Transfer (Question 1 and 1b)		Forward-Reaching Transfer (Question 2 and 2b)	
Level of Performance	**Representation**	**Connections**	**Communication**	**Connections**	**Communication**
Exemplary **3**	The student used more than one and/or one unique math representation to help solve the problem and explain his/her work in thoughtful way. All of the student's representations are labeled and correct.	The student made a mathematical connection to a previously learned math concept, strategy, or solution method. He/she provided a specific example of the math connection.	The student's thinking was clear. He/she used a lot of specific math language to express thinking.	The student made a specific and detailed connection to a different problem that could be solved in the same way. He/she wrote a new example of a problem that could use a similar solution method or mathematical strategy.	The student's thinking was clear with specific math language. His/her example problem is complete with all components to solve. He/she also showed the strategy at work.
Proficient **2**	The student used a math representation to help solve the problem and explain his/her work, and it is labeled and correct.	The student noticed some type of mathematical connection from past experiences and noted it in some way, but did not provide a clear example.	The student's thinking was relatively clear with some math language.	The student explained how the strategy could be used on a future problem, but did not provide a clear or correct example of a new problem.	The student's thinking was relatively clear with some math language. The example problem is legible, but may be difficult to follow.
Emerging **1**	The student tried to use math representation to help solve the problem and explain his/her work, but it has mistakes in it.	The student tried to make a connection, but it is not about the math in the problem, and/or the connection is missing adequate detail for understanding.	The student's thinking is somewhat understandable, but needs further development. He/she uses very little math language.	The student attempted to explain how the strategy could be used on a future problem, but used the strategy incorrectly.	The student's explanation is incomplete and missing sufficient detail. He/she only duplicated the same problem with different surface features.
Not Evident **0**	The student did not use a math representation to explain his/her work.	The student failed to make any connection to past learning.	The student's thinking is incomprehensible and uses no math language.	The student provided an irrelevant example, or none at all.	The student is unable to provide any example at all.

Appendix D

Pre/Posttest Transfer Questionnaire

Name: ______________________________________ Date: _______________

Directions: Answer each question below the best you can.

1. What is backward-reaching transfer? Give the definition AND a clear example.

Definition:____

____

____

Example:____

____

____

2. What is forward-reaching transfer? Give the definition AND a clear example.

Definition:____

____

____

Example:____

____

____

Appendix E

Pre/Posttest Rubric

Level of Performance: Definition		Level of Performance: Example	
Backward-Reaching Transfer	**Forward-Reaching Transfer**	**Backward-Reaching Transfer**	**Forward-Reaching Transfer**
Exemplary **3** The student's thinking was clear. He/she provided a correct definition of the concept.	**Exemplary** **3** The student's thinking was clear. He/she provided a correct definition of the concept.	**Exemplary** **3** The student provides a clear example that shows a connection between two problem-solving activities.	**Exemplary** **3** The student provides a clear example that shows a connection between two problem-solving activities.
Proficient **2** The student's thinking was relatively clear with a sufficient definition of the concept.	**Proficient** **2** The student's thinking was relatively clear with a sufficient definition of the concept.	**Proficient** **2** The student provided an example that shows a connection, but did not fully and/or accurately explain.	**Proficient** **2** The student provided an example that shows a connection, but did not fully and/or accurately explain.
Emerging **1** The student's thinking is somewhat understandable, but needs further development. He/she does not have a clear understanding of the concept	**Emerging** **1** The student's thinking is somewhat understandable, but needs further development. He/she does not have a clear understanding of the concept	**Emerging** **1** The student's example is not clear, but does show a partial connection.	**Emerging** **1** The student's example is not clear, but does show a partial connection.
Not Evident **0** The student's thinking is incomprehensible and fails to define the concept.	**Not Evident** **0** The student's thinking is incomprehensible and fails to define the concept.	**Not Evident** **0** The student fails to provide an example or does not provide a relevant or accurate example.	**Not Evident** **0** The student fails to provide an example or does not provide a relevant or accurate example.