ABSTRACT

THE EFFECTS OF ALTERNATIVE READING AND MATH STRATEGY TREATMENTS ON WORD PROBLEM-SOLVING

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This study examines the relationship between reading comprehension and mathematical word problem-solving. Specifically the study utilizes a single-subject alternating treatments design to compare three different math word problem-solving treatments and their effects on solution accuracy for three third grade students who were exhibiting difficulties in reading and math. The three treatments consisted of a reading fluency and comprehension intervention, a math strategy intervention, and an intervention that integrated both strategies. The current study did not result in conclusive findings regarding the relative effectiveness of the three treatments, but did begin to show some promising trends that suggest the importance of including reading comprehension components to math word-problem lessons and interventions. The current study discusses both the results and limitations of the study, and provides recommendations for further research.
THE EFFECTS OF ALTERNATIVE READING AND MATH STRATEGY TREATMENTS ON WORD PROBLEM-SOLVING

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The Effects of Alternative Reading and Math Strategy Treatments on Word Problem-Solving Ability

The ability to solve problems using mathematical reasoning is a key to success in various situations and contexts throughout life. Capabilities in mathematical reasoning are necessary in many varying contexts from careers in such professions as science, engineering, and business to the computation of gas mileage to the comparison of prices of multiple product brands. Due to the ubiquitous and often eclectic situations in life that require mathematical reasoning to find various solutions, the mathematics component of education has been recognized as crucial enough to even affect public policy. The importance of mathematical ability has grown so great that the No Child Left Behind Act mentions mathematics specifically as criteria in the Annual Yearly Progress report cards that facilitate the accountability requirements of local education agencies to the federal government (U.S Department of Education, 2007).

The public and political attention notwithstanding, mathematics has been prevalent in schools for years, and it is common knowledge that the practice of assigning and testing with word problems is the method of choice when providing instruction on mathematical reasoning beyond simple computational skills. Word problems describe various situations and contexts ranging from the contrived to true-to-life descriptions, and generally ask questions about the situation whose answers depend on requisite mathematical skills. Because they require the student to go through an analysis to relate important ideas to each other, discard information that is not required, and choose a mathematical algorithm, word problems are generally more difficult to solve than simple computational problems. The question, then, becomes how educators can better facilitate the growth of mental processes in their students that are required to solve word problems.

Purpose

Word problems are generally given in a textual format that requires the student to comprehend what the problem content is conveying regardless of the mathematical curriculum or intervention strategy that is being instructed. The purpose of the study, then, is to examine the effects of a repeated reading treatment on the ability to correctly answer simple addition and subtraction word problems for third and fourth grade students who possess deficiencies in reading and math. The objective is to compare the effectiveness of the repeated reading treatment
with a mathematical strategy intervention in reducing inaccurate answers to word problems for the aforementioned population.

Research Questions

Accordingly there are two questions that will be addressed in this study. The first concerns how a repeated reading treatment and a math strategy treatment compare in their effectiveness to reduce inaccurate answers to word problems for third and fourth grade students who are deficient in reading and math. The second question is similar to the first except that it addresses the effectiveness of a strategy that combines repeated reading and mathematical strategy to the same population. The formulation of the second question concerns how the effectiveness of the combined strategy compares to that of its two components, namely repeated reading and math strategy, when administered separately.

Hypotheses

Upon examination of the effects of the three treatment alternatives it is expected that the administration of the combined treatment will result in less instances of incorrectly answered word problems than administration of the math strategy alone, which in turn, will result in less instances of incorrectly answered word problems than the administration of the repeated reading intervention.
Review of the Literature

Mathematical Problem-Solving Interventions

The logical initial focus when considering aid for students in solving mathematical word problems is to concentrate on interventions that are specifically designed to intervene in the area of word problem solving. Unfortunately most of the research that has been conducted in the area of math interventions has focused almost exclusively on basic computational skills; only a handful of studies have examined treatments for solving word problems (Xin & Jitendra, 1999).

Interventions that have addressed word problem solving generally employ one of only a few techniques including representational approaches wherein the student is taught to gain understanding of the problem via pictorial drawings, concrete manipulative objects, mapping techniques, etc., strategy training wherein, problem-solving heuristics are taught via direct instruction and/or cognitive and metacognitive strategies, and computer-aided instruction (CAI) (Xin & Jitendra, 1999). The effectiveness of all three strategies is reported as moderate to large in terms of effect sizes (Xin & Jitendra). There is, however, some confusion in the literature base regarding the effectiveness of computer-aided instruction. In the meta-analysis conducted by Xin and Jitendra CAI interventions produced the largest mean effect size, whereas in the meta-analysis conducted by Kroesbergen and Van Luit (2003) CAI interventions produced the lowest effect sizes. The high effect size reported by Xin and Jitendra may be more due to the strength of the underlying curriculum or may have had elements of direct instruction. For instance one CAI intervention involves reading a word problem in manageable pieces, creating a mathematical statement (with or without the help of manipulative objects), and then producing an answer (Stellingwerf & Van Lieshout, 1999). The intervention is administered by a computer program that provides the problems and the manipulative objects, however, the underlying strategy may be more paramount than the presence of a computer.

To follow up on the idea of the appropriateness of strategy instruction, Xin and Jitendra (1999) report that representational approaches produce larger effect sizes than strategy, however, it is undoubtedly effective because it aids in problem-solving strategy selection. This flows logically from the fact that representational methods can facilitate the selection of an appropriate strategy to use for a particular problem. This idea is supported by the literature. For instance consider a schema-based strategy, which utilizes a technique whereby a word problem is mapped
into an appropriate diagram (Jitendra, Griffin, McGoey, Gardill, Phat, & Riley, 1998). Schemata don’t necessarily have to exist as physical diagrams, but can be purely mental constructions as well. It can be argued that all children map word problems into one of their representational schemas that then map to appropriate computational operations (Leong & Jerred, 2001; Pape, 2003). However the very act of mapping the problem to a diagram facilitates the selection of a strategy because the mappings, or problem schemata, are associated with appropriate solution strategies, or action schemata whether or not the schemata are mental or physical representations. Another treatment involves circling key terms in the problem in conjunction with representing the problem in a sketch (Case, Harris, & Graham, 1992). The key terms are associated with an appropriate strategy, or mathematical operation, to use when solving the problem. Pictures, facilitated by sketches, can similarly aid in strategy selection. Both studies have high reported effect sizes ($d = 0.64$ and $d= 1.56$ respectively) (Kroesenbergen & Van Luit, 2003). It becomes clear, then, that the representation of a problem only facilitates word problem solving insofar as it helps the student to select an appropriate problem-solving strategy.

*The Importance of Reading Skills to Mathematical Comprehension*

The ability to represent a word problem is not a rudimentary skill. The necessary prerequisite is the ability to comprehend the content of the problem in the first place. Reading skills play a role in the facilitation of understanding problem content, and thereby solving word problems, because word problems are generally presented in textual format. This is supported by research going back decades. Call and Wiggin (1966) conducted a study wherein two different methods were employed in the instruction of algebra; one method stressed reading skills such as vocabulary, definitions, and prose translation into mathematical statements, and the other employed more traditional instructional techniques (as cited in Aiken, 1972). The results of a mathematics criterion test demonstrated the efficacy of the reading approach over that of the traditional approach.

Other research studies tend to lend support to these conclusions. A widely-cited review of the literature examining the effects of reading ability on mathematical ability includes a study conducted by Martin (1964) that found that reading skills may be even more crucial than skills in computation when it comes to problem-solving abilities (as cited in Aiken, 1972). This result was supported in a more contemporary study wherein students with a math disability but not a reading disability were compared to students who were comorbid in both disabilities in their
abilities to employ computational operations and problem solving with several classes of word problems (Fuchs & Fuchs, 2002). Fuchs and Fuchs found that although both groups performed comparably on computational operations, the group with only a math disability performed better at problem solving than the group that had comorbid math and reading disabilities.

These results make sense when considering that the actual text that constitutes word problems must be understood before the word problems can be translated or transformed into the correct mathematical statements and operations. Literature from both schema and other strategy selection approaches to problem solving support this notion. Many word problems contain superfluous information, or employ inconsistent language meaning that they are worded in such a way that it encourages mistranslation into an erroneous schema (Leong & Jerred, 2001; Pape, 2003). If one chooses to use another method such as that described above by Case et al. (1992), then part of the procedure is recognizing key words. Therefore comprehension of the actual text is vital in order to successfully employ any strategy selection method.

There are various factors that support a person’s ability to read such as phonemic awareness, phonics, definitions and vocabulary, reading fluency, and reading comprehension (Therrien, 2004). All of these factors are critical, but the factor that provides the link between reading ability and mathematical problem-solving ability is the one that builds on the others, namely reading comprehension. Martin (1964) reported that the partial correlation between the two when the analysis controlled for computational ability was higher than the partial correlation of problem-solving ability and computational ability when the analysis controlled for reading comprehension (as cited in Aiken, 1972). Once reading comprehension is achieved there is a higher potential for a student to read and understand the mathematical language with which word problems are often composed. The ability to comprehend the prose can then facilitate the reading of mathematics as its own language composed of not only words but also numerals and other symbols (Adams, 2003).

*Facilitating Reading Comprehension via Repeated Reading Strategies*

Since the research base lends support to the idea that reading comprehension is important to success in mathematical problem solving, strategies that aid in the growth of reading comprehension also become important. One of these is designed to target reading fluency primarily, but also has been shown in some studies to support comprehension. Repeated reading is an intervention strategy whereby a student is asked to read a passage aloud multiple times.
There is a wide literature base that supports the notion that repeated reading increases fluency. In a meta analysis of 18 studies, Therrien (2004) found that there was a moderate effect size in fluency for transfer measures that focused on the ability of students’ fluency on new passages after having read different passages multiple times (\(ES = .50\)), and a high effect size in fluency on non-transfer measures that focused on students’ fluency on the same passage after it had been read multiple times (\(ES = .83\)). Incidentally, the formula described for effect size calculations in Therrien’s meta-analysis is equivalent to the calculation for Cohen’s \(d\), even though the effect sizes were reported generically as “ES”. Further support for the efficacy of repeated reading on fluency comes largely from the studies included in Therrien’s analysis. For instance, one study compared repeated reading to non-repetitive strategies and found that repeated reading compared favorably to non-repetitive methods (Homan, Klesius, & Hite, 2004). Another study supported the efficacy of repeated reading in dependent measures of practice, within story effects, and across story effects with readers in the second grade who were beginning to transition from learning to decode the words to fluent reading (Dowhower, 1987). The study found that speed, accuracy, and comprehension were increased through the use of repeated reading.

Fluency is not comprehension, but it is difficult for comprehension to occur without fluency. Fluency enables the reader to focus his or her attention on the content of a passage rather than on the decoding of words. If fluency is low the reader must focus so intently on decoding words and their meanings that comprehension becomes inhibited (Laberge & Samuels, 1974). Once fluency becomes automatic, other components of comprehension such as the activation of prior knowledge and the organization of ideas can take effect. Along with fluency gains, analysis has shown moderate effect size gains in reading comprehension through repeated reading in both transfer and non-transfer measures (Therrien, 2004). The other studies comparing repeated reading to non-repetitive strategies and comparing the effects of repeated reading with transitional readers also showed gains in reading comprehension in their results (Dowhower, 1987; Homan et al., 2004).

It must also be noted that word decoding fluency is not the sole factor constituting comprehension of text. Vocabulary is also an important element. This is especially true in mathematical problem descriptions wherein words are often used to reflect meanings that differ from more prevalent uses of the word (e.g., volume, product, etc.), and in other cases words are employed that are homonyms to other prevalent words (e.g., “sum” and “some”, ”whole” and
“hole”, etc.) (Adams, 2003). While the importance of vocabulary is acknowledged, it does not have the greatest association with factors that cause difficulties in learning to read; this honor belongs to phonological coding deficits (Vellutino, Fletcher, Snowling, & Scanlon, 2004). Vellutino et al. (2004) arrived at this conclusion through a comprehensive review of the literature regarding reading disabilities over a period of 40 years. Therefore it seems logical to state that the more fluent a child is when reading a body of text (i.e., the more efficient the child is at the process of phonologically decoding words), the more likely it is that the child will comprehend the text. This logical inference is backed up by a study conducted by Kuhn and Stahl (2003), that, in addition to other things, finds that automaticity, or the ability to be fluent without requiring specific attention to decoding, is a critical factor in constructing meaning from text. Kuhn and Stahl further conclude that strategies such as repeated reading are effective due to the increased time spent in reading connected text, which also lends further support for the use of repeated reading as an intervention strategy.

Once the child can comprehend the text, any issues with vocabulary can be dealt with, but if the child cannot even decode the words in a fluent manner, then concentration on vocabulary will be of minimal aid. Even Adams (2003), whose study focuses on the issues surrounding vocabulary in connection with word-problem solving, admits that text decoding is a necessary skill before critical information, including that which may cause problems due to vocabulary issues, can be mined from the problem description.

Summary

Even though reading comprehension has been shown to be crucial to mathematical problem solving, reading instruction is not consistently prevalent in mathematics classrooms. A study examining how much various mathematics instructors incorporated reading instruction into their mathematics lessons found that, although some teachers employed vocabulary lessons and comprehension probing questions, they did so with varying degrees of consistency (Carter & Dean, 2006). The importance of reading instruction cannot be overlooked, and repeated reading as a strategy aids in comprehension gains via its positive effect on fluency rates. However, no study was found that linked repeated reading directly with mathematical word-problem solving, especially for students with disabilities in reading. In fact there are very few studies that exist that even purport to examine the link between reading comprehension and word-problem solving, much less the link between a specific strategy such as repeated reading and solving.
word-problems (Hall, 2004). The study that comes closest to linking repeated reading with solving word-problems comes from Pape (2003), wherein he found that the number of re-readings had no significant effect on reducing errors for word problems that were worded with inconsistent language. However, “re-readings” were not coded as actual full repeated readings of the text; rather re-readings were counted even if the student only reread a partial segment of the word problem. In addition no attempt was made to determine whether or not the student was rereading the problem silently. Therefore the case can still be made for the paucity, or even complete lack, of the examination of the link between repeated reading and word problem solving within the literature base.

The potential for the effectiveness of repeated reading in increasing problem solving ability arises from the indirect link via reading comprehension. Once a student comprehends a word problem sufficiently enough to represent it, it is much more likely that an appropriate strategy will be selected, which is more likely to lead to a correct answer. From the results of the examination of the literature it is expected that the use of a repeated reading strategy, in conjunction with a mathematical intervention that incorporates strategy instruction and representational techniques, will have a positive effect on a student’s ability to solve mathematical word problems.
Research Design

Participants

Student Participants. Four students were selected from the population of third grade students attending a small-town middleclass Midwestern elementary school. The criteria for participation were failure to meet grade level benchmarks on AIMSWEB math and oral fluency probes (DIBELS oral fluency probes for the 3rd and 4th grades may also be used). Other criteria include a special education classification of LD due to deficiency in reading and math, teacher indications of difficulties in mathematical word problem solving and reading comprehension, and the absence of any physical handicap or motor difficulties.

Materials

Math Word Problem Probes. To establish a baseline each student received four mathematical word problem mini-probes. Each mini-probe contained 4 questions randomly selected from a set consisting of 6 addition problems and 6 subtraction problems. The set of problems consisted of the six problem types listed in Figure 1.

In addition mini-probes were administered after every treatment. There were originally to be 54 mini-probe administrations in all (1 mini-probe after each of the 3 treatments plus a control treatment for 12 alternating treatment sessions, and 6 mini-probes, or 1 for each replication session). However, the treatment sessions were trimmed down from 12 to 8, and no replication phase was required so the actual number of mini-probes administered was 32. Each mini-probe contained four problems randomly drawn from the six problem types in Figure 1. Half of the mini-probes were addition, and the other half subtraction. The mini-probes were printed on colored paper to aid in the cueing of the correct treatment. In addition there were duplicates of all probes for researcher use.

Math Word Problem Worksheets. For the purposes of problem-solving practice, 40 worksheets were originally thought to be required (3 worksheets for each of 12 sessions plus 4 worksheets, or 1 for each replication session), each containing 6 problems representing each of the problem types shown in Figure 1. However the session sequence was trimmed from 12 sessions to 8 and no replication phase was required. Therefore only 32 worksheets were utilized in actuality. Similar to the probes, half of the problems were addition problems and the other half subtraction. In addition each worksheet was printed on colored paper to aid in the cueing of the correct treatment, and there were duplicates of all worksheets for researcher use.
Figure 1. These are the classes of problems to be used in the study. These problems were used in another study that employed the same math strategy intervention (Case, Harris, & Graham, 1992).

Treatment Script and Treatment Integrity Checklist. A treatment script was created to aid the researcher in administering the treatments. The treatment script appears in Appendix A. A script was made for each of the three treatments as well as the control treatment. Treatment integrity was monitored via a treatment integrity checklist that was based on the treatment script. The checklist appears in Appendix B. The researcher had another researcher observing 25% of the treatment sessions, or 3 treatment sessions per student participant, utilizing the integrity checklist as a guide. The requirement of treatment integrity was considered fulfilled if at least 80% of the total number of checklist items is adhered to in each observation session.

Experimental Design and Procedures

To test the hypotheses a single-subject alternate-treatment design was employed using block rotation. The effects of the independent variable (i.e., the treatment employed with three levels consisting of repeated reading, math strategy, or combined treatment) on the dependent variable (i.e., number of correct digits in answer) was measured. A control condition served as
an additional independent variable wherein the student participants simply read the problem once out loud, and then solved the problem. This control condition was intended to add to the control of the baseline to help facilitate discussion on the efficacy of multiple treatments in the event that no one treatment proves to be significantly more effective than the others. However as time went on it became evident that that the control condition ceased being a pure “control condition” once the treatments began due to learning effects from the other three treatments, and so was not considered in the data analysis (see the Data Analysis and Results sections). Probe completion time was also measured as a secondary dependent variable to facilitate consideration of the practicality and efficiency of the most effective treatment. For instance, if one treatment was found to be the most effective, but caused the student to take an inordinate amount of time to solve the word problems, then the practicality of the treatment may be called into question due to its possible lack of efficiency.

Originally prior to establishing a baseline each student participant’s reading ability was to be assessed if it could not be obtained from already existing data. In the case of the selected student participants the school psychologist assured that they were all on IEPs for deficiencies in reading and math. Subsequent to discussions with the school psychologist and special education teachers about the participants’ reading and math abilities, a baseline was established via the number of digits correct for each of four different probes to be administered to each of the four participants. After baseline data was collected three alternating treatment sessions per week over a period of four weeks were administered for each participant. Each session consisted of administration of each of the three treatments (repeated reading, math strategy, and combined) as well as a mini-probe for the control condition.

The repeated reading strategy consisted of reading the problem out loud four times with any errors corrected by the administrator. The math strategy intervention is based on the strategy in the study done by Case, Harris, and Graham (1992) whereby the student reads a problem once out loud, circles key words, visualizes the problem via drawing a picture, writes a mathematical statement, and then calculates the answer. The combined treatment is the same as the math strategy except during the first step the problem is read out loud four times with error correction provided each time. As previously mentioned, the control condition treatment consists of reading the problem out loud one time only followed by solving the problem.
The 4 treatments were administered as a block with a randomly determined sequence. Each treatment was given in succession during every session in the randomly chosen order for that session. For instance, if the sequence for a particular session is repeated reading, math strategy, control, combined, then the administrator administered the script for teaching and practicing repeated reading, then administered a mini-probe, then administered the script for teaching and practicing the math strategy, then administered a mini-probe, and so forth. The only treatment that was not taught was the control condition since the participant was expected to solve those problems in any way they could. For each mini-probe, the administrator ensured that the participant utilized the strategy that was just practiced. The worksheets and mini-probes were color-coded to help cue the participant as to which strategy to use.

The block rotation schedule was counterbalanced between sessions to help minimize any carryover and sequencing effects. Counterbalancing requires that the student participant be exposed to each treatment in a session, each treatment is presented an equal number of times throughout the alternating treatment phase, each treatment is presented in the same position an equal number of times, and each sequence of treatments is presented an equal number of times. If the first two treatments took longer than 30 minutes, then each block of 4 treatments were to spread over two sessions. In addition to the use of the counterbalancing technique, carryover effects were further minimized by the fact that the same carryover effects will probably occur between every treatment instance, which will help cancel out their influence. Data was collected between each treatment with a mini-probe, and after the mini-probe the next treatment was cued. Each day the dependent variable of number of digits correct was measured by counting the number of correct digits for each word problem in each of the four mini-probes given in that session.

To establish a functional relationship between the treatment and word problem-solving accuracy, a replication phase was to be conducted after the final block treatments phase. During this final phase the treatment that was most effective in reducing word problem inaccuracy was be administered for four sessions. During this session data was to be collected via the administration of four different probes similar in nature to the probes used for the baseline phase. However, the replication phase was not conducted for this study as there was no significant difference between treatments (see Results section).
Data Analysis

The measures of the dependent variable were recorded graphically for the baseline and alternating treatments phases. Curves for each treatment are shown together on the same graph in the alternate treatment phases. The X axis represents sessions, and the Y axis number of digits correct in word problem answers. Analysis was conducted via visual inspection of the graphical displays.

In the course of data analysis three issues were decided. First one student was dropped from the study and was not included in the analysis due to chronic scheduling conflicts during the alternating treatments phase. The second issue was that of the baseline data. Originally it was proposed to collect four data points per participant, but again, due to scheduling conflicts and absences the researchers were only able to collect three data points in some cases. Therefore the first three data points collected for each student were included in the analysis and all subsequent data points were dropped for purposes of comparison across participants. The third issue had to do with the control condition that was measured during each session in the alternating treatments phase. This condition was to extend the baseline into the treatments phase, but it was discovered that this control condition could not serve as a pure “control condition” because of learning effects from the other treatments during the alternating treatments phase. This made the control condition data worthless for the purposes of data analysis, and therefore was not included in the study results.
Results

Figures 2, 3, and 4 show the results for each of the 3 students included in the study.

Figure 2: Results for Student 1

Figure 3: Results for Student 2

Figure 4: Results for Student 4
One of the original 4 participants had to be dropped from the study due to scheduling conflicts.

There are two graphs for each student: one depicting results in terms of digits correct in the probes, and the other depicting the average number of minutes it took to solve a problem for each mini-probe. Originally the baseline was to consist of 4 data points for each participant, this was trimmed to 3 because of the difficulty the researchers had in obtaining 4 data points for each student.

The results show the efficacy of all three forms of treatment as the results for each treatment are consistently above the baseline for students 1 and 2. Student 4 had a high baseline to begin with, and so those results hit a ceiling very quickly. The data for the other students also tended to hit a ceiling although it wasn’t as consistently hit as it was for student 4.

Unfortunately none of the three treatments stood out as more effective than the others for any of the students. However when looking closely at the data displays there are some trends that tend to stand out. First, in two of the cases, the variability of the results for the repeated reading and math strategy combination treatment is somewhat less than the math strategy treatment, and all three cases show a greater variability for the repeated reading strategy as compared to the combined treatment. The other trend that tends to stand out is that the combination strategy produces the highest results more consistently than any of the other strategies. Interestingly in the cases of students 1 and 2 the math strategy alone doesn’t fare much better than the repeated reading strategy alone and in fact is sometimes among some of the lowest scores that were received on some treatment days. The results for combination strategy are fairly consistently among the highest scores received on each day of treatment across each student.

The other data set collected for each student was average time to problem completion. These are also shown in the second set of graphs for each student in Figure X. The results show a fairly clear delineation of time to problem completing among the three treatments with the combination strategy almost always taking longer than the repeated reading strategy, which takes longer than the math strategy. All of the treatments took longer than the baseline. Also, in general, the average time to problem completion for each treatment strategy decreased over time, although for the combination strategy there is quite a bit of variability when compared to the other strategies. The only notable exception to this trend is the math strategy treatment for
Student 1 whose time tended to increase over time until about half way through the treatment sequence, before it started to decrease.
Discussion

The results of the study did not show that any treatment proved to be more effective than the others, which contradicts the hypotheses that the results for the combination strategy would prove more efficacious than the math strategy, which would in turn prove more efficacious than the repeated reading treatment. However, it is interesting that the trends in the data seem to suggest, however slightly, some agreement with the hypothesis that the combination strategy is more effective than the other two by themselves. The trends across student show that the combination treatment produces among the best results, and therefore, if a ceiling had not been hit in the data so soon it is reasonable to predict that the combination strategy would have proved more effective than the others over time. The data trends do not tend to support the hypothesis that the math strategy would prove more effective than the repeated reading treatment, and in fact, for students 1 and 2 at least the repeated reading strategy seems to have produced equal or better results than the math strategy treatment.

These trends are important because they begin to suggest, and therefore begin to provide some support for, the importance of reading to the process of solving math word problems. In order to solve these problems it is necessary to formulate a strategy, but it is also necessary to be able to read and comprehend the problem in the first place. The combination strategy that combines the two elements of repeated reading and math strategy produced the most effective “trend” in the data throughout the three students in the study. In case of students 1 and 2 it is also interesting to note that the repeated reading treatment often produces more effective results than the math strategy treatment alone, which would tend to contradict the hypothesis that math strategy would prove more effective. This is not the case with student 4 who may not have had as much initial difficulty in the areas of math and reading as was initially thought.

Whether the repeated reading or the math strategy proved more effective than the other is probably not as important as the trend that suggests the overall effectiveness of the combined strategy. What this basically begins to support is that comprehension of the math word problem is not as effective without thinking through a strategy to use and vice versa. In fact it was noted during treatment that when the student was not asked to go through the repeated reading exercise he or she often jumped right to a strategy without trying to understand the problem in any way. This often resulted in missed problems due to the use of addition when subtraction was called for and vice versa. Perhaps then it may be even more important to comprehend the word problem
than to memorize a strategy because in understanding the problem a strategy may more easily present itself whereas a strategy without understanding of the problem is merely a “shot in the dark.”

The results for time to problem completion indicate an expected trend in that the combined treatment often added a minute or more to the time it took to complete a problem than the repeated reading and math strategy required. This is expected because the combined strategy required more thinking about the problem both in terms of comprehension and in terms of strategy utilization. What is more interesting is that the repeated reading often took more time than the strategy utilization. On the one hand this is to be expected because it takes time to read a problem four times in a row; however it is interesting because the math strategy took the least amount of time in most cases and yet tended to produce the least accurate results on the mini-probes. It further supports the idea that taking the time to comprehend a problem may increase the time required to solve it, but when this happens the solutions are accurate on a more consistent basis. In fact, when looking across all three treatments the more time it took to solve the problem, the more accurate the treatment proved to be in general, at least as trends in the data tend to show.

Based on these results it is recommended that teachers and tutors begin with facilitating reading comprehension of a word problem prior to utilizing a strategy when teaching a student how to solve them. This could take a number of forms including discussions about vocabulary – especially terms that may indicate a strategy, content-related questions about what the problem is about, discussions of what information appears useful and which information may be superfluous, discussions of which pieces the student logically understands and which pieces are confusing, and the use of graphic organizers. Once the problem is thoroughly understood the educator can then move on to choosing a strategy or developing a schema to use in solving the problem. This would not only increase the likelihood that the student chooses the correct strategy, but would also aid the student with his or her reading comprehension skills in general. If students can learn to apply reading comprehension techniques to simple word problems in elementary grades, it will be easier for them to generalize these skills when encountering problems in more advanced mathematics curricula.
Limitations

Even though the data trends tend to support the relationship between reading and math word problem solving as well as its importance, the data set does not conclusively support the supremacy of any one treatment. This is due to several limitations that occurred throughout the data collection process. One of the biggest limitations was the lack of control the researcher had in obtaining student subjects for the study. Meetings were held with the school psychologist and special education teachers at the school that were utilized to set forth the parameters required by the study. However in at least one case the student was not having the difficulty in reading or math that the researcher anticipated, and none of the students were having the degree of difficulty in math that was initially thought. As a result, even though the baseline data generally show a weakness in solving the word problems, once the treatments were administered the increase in accuracy was immediate and sustained despite some variability between treatments. This tended to create a ceiling effect early on in the data collection sequence that hampered the ability for any one treatment to prove superior to the others in anything like a conclusive manner.

In addition, the mini-probes that measured the effectiveness of the treatments were limited in problem quantity to guard against student fatigue. Since the school schedule was such that each student could only be seen once per week, every treatment had to be given in each session. However the side-effect of this was that the mini-probes did not contain very many problems, and therefore did not allow for as much variability that the study may have required. This proved to be another factor that exacerbated the ceiling effect of the study. In fact this lack of variability required that we use digits correct as the dependent measure rather than problems correct or even problem where the correct strategy was utilized, which may also have skewed some of the data.

The other factor that may have limited a treatment from producing more positive results than the others is the possible learning effects across treatments. Even though in theory these learning effects should occur across every treatment, and therefore cancel out as a confounding variable, in reality the students often used the math strategy during the repeated reading strategy, or may have read the problem multiple times during the math strategy treatment. It was difficult to ascertain when this occurred because the student did not always write down the strategy steps or read the problem multiple times out loud when not required to do so. However this undoubtedly began to have effects early on, and may have confounded the study.
To mitigate these problems in the future there are several things that can be done. The single most important factor would be for the researcher to work with each student at least 2-4 times per week, with the treatments spread across each session rather than applied all at once in one session. This by itself may help mitigate learning effects across treatments. This would also reduce the danger of fatigue and allow the researcher to create measurement probes that are longer, which would provide more room for variability in accuracy and scoring. This would reduce the likelihood of a ceiling effect in the data which would confound the study. The other important item would be to work closer with the school staff to find students who are having difficulty in math and reading. It may also help to administer an achievement test to the students after they have been selected, and then create probes and worksheets that are based on their abilities rather than trying to fit the students to the difficulty level of the measures. A study that replicated this study with those changes incorporated would be an extremely valuable study that would shed further light on the relationship and importance of reading comprehension to mathematical word problem-solving.
Appendix A
Treatment Scripts

The following pages depict procedural scripts for the various treatments. The strategic treatments proceed first with a teaching phase using a worksheet, and then a measurement phase utilizing a mini-probe. The control condition utilizes a mini-probe only since there is no teaching required for that case.

After all treatments for a student are completed for the day, the number of correct digits for each word problem will be totaled, and recorded at the top of the completed mini-probe next to the time it took to complete.
Treatment Script: Control Condition

Control Condition Mini-Probes:

1. Select a red mini-probe set, separate the two copies, and put one in front of the student face up.

2. Say to the student, “Now let’s see if you can solve these problems without so many instructions. When I say ‘Begin’ solve these problems just like we practiced. For each problem read it out loud one time, and then solve it however you can. Then circle your final answer and move on to the next problem. If you decide you can’t finish a problem just move on to the next one. When you are finished with all of the problems turn your paper over or say ‘I am done.’ Remember to read each problem out loud before solving it.”


4. Start the stopwatch as soon as you say “Begin”

5. When the student indicates that he or she is finished stop the stopwatch, and record the time on top of the student’s mini-probe.

6. Tell the student “Thank you.”
Treatment Script: Repeated Reading

NOTE: Flexibility IS permitted!! The point is for student comprehension, not standardization

Repeated Reading Worksheets:
1. Select a green worksheet set, separate the two copies, and put one in front of the student face up.
2. Say to the student, “Now we are going to use the green sheet where we read each problem over and over 4 times.”
3. Hand a pencil with an eraser to the student.
4. For each problem on the worksheet point to the beginning of the problem and say to the student, “When I say ‘Begin’, please read this problem out loud. If you have trouble with a word I will help you. Ready? Begin.”
   a. Follow along with the student. If the student reads any word incorrectly or hesitates for 3 seconds tell the word to the student.
5. For the next 3 iterations say to the student, “Thank you. When I say ‘Begin’ please read the same problem again exactly as before. If you have trouble with a word I will help you. Ready? Begin.”
   a. For each iteration follow along with the student. If the student reads any word incorrectly or hesitates for 3 seconds tell the word to the student.
6. Say to the student “Now when I say ‘Begin’ please figure out the answer to this problem. You may write anything you feel is necessary in the space below the problem. Please draw a circle around your final answer, and put your pencil down. If you can’t solve the problem then say ‘I am done’ and put your pencil down. Ready? Begin.”
7. When the student indicates that he or she is finished, say, “Thank you”
8. Repeat steps 3 – 7 for each problem.

Repeated Reading Mini-Probes:
1. Select a green mini-probe set, separate the two copies, and put one in front of the student face up.
2. Point to the first problem and say to the student, “Now let’s see if you can solve these problems without me giving you so many instructions. When I say ‘Begin’ solve these problems just as we practiced. For each problem read the problem out loud 4 times. I will help you if you get stuck. Then solve the problem and draw a circle around your final answer. When you are finished turn your paper over or say, ‘I am done.’ If you decide you can’t answer a problem then move on to the next one. Remember - read each problem out loud 4 times before solving it.”
4. Start the stopwatch immediately after saying “Begin.”
5. For each problem follow along with the student while he or she reads the problem. If the student reads any word incorrectly or hesitates for 3 seconds tell the word to the student.
6. When the student indicates that he or she is finished, stop the stopwatch and say, “Thank you”. Record the time on top of the student’s mini-probe.
Treatment Script: Math Strategy

NOTE: Flexibility IS permitted!! The point is for student comprehension, not standardization

Math Strategy Worksheets:

1. Select a yellow worksheet set, separate the two copies, and put one in front of the student face up.
2. Say to the student, “Now we are going to use the yellow sheet where we circle words and draw pictures.”
3. Give the student a pencil with an eraser
4. For each problem on the worksheet teach the student to do the following:
   a. Read the problem one time out loud with no help from the researcher.
   b. Circle any of the following phrases that appear in the problem, and explain how the phrase indicates the required operation. Feel free to model and use examples.
      i. “more than” – addition
      ii. “how many” and “in all” – addition
      iii. “how many” and “have left” – subtraction
      iv. “how many more (or fewer)” – subtraction
      v. “how much more” – subtraction
      vi. “the rest are” – subtraction
   c. Draw a picture of the problem. Since these are all problems that deal with joining, combining, comparing, or separating objects, the pictures should show the two different sets of objects given by the problem.
   d. Write out a mathematical statement. This just means to have the student write either one of the following:
      i. \( X + Y = \)
      ii. \( X - Y = \)
   e. Write the answer; in other words do the arithmetic.
5. When all of the problems are finished say to the student. “Thank you.”

Math Strategy Mini-Probes:

1. Select a yellow mini-probe set, separate the two copies, and put one in front of the student face up.
2. Say to the student, “Now let’s see if you can solve some problems without my help. When I say ‘Begin’ please solve each of these problems. Remember to follow the same steps that we did with the worksheet: First read the problem one time out loud, then circle the appropriate phrase, then draw a picture, then write the addition or subtraction problem, and then solve the problem. When you finish a problem continue to the next problem. When you are finished with all of the problems turn your paper over or say ‘I am done.’ Remember to read each problem out loud first.”
4. Start the stopwatch as soon as you say “Begin”
5. For each problem ensure that the student is following the strategy. If they are not then say, “Please remember to follow the steps that we practiced: [insert missing step].”
6. When the student indicates that he or she is finished stop the stopwatch, and record the time on top of the student’s mini-probe, and tell the student, “Thank you.”
Treatment Script: Combined Strategy

NOTE: Flexibility is permitted!! The point is for student comprehension, not standardization

Combined Strategy Worksheets:

1. Select a blue worksheet set, separate the two copies, and put one in front of the student face up.
2. Say to the student, “Now we are going to use the blue sheet where we read each problem over and over 4 times, and then circle words and draw pictures”
3. Give the student a pencil with an eraser.
4. For each problem on the worksheet teach the student to do the following:
   a. Point to the beginning of the problem and say to the student, “When I say ‘Begin’, please read this problem out loud. If you have trouble with a word I will help you. Ready? Begin.”
      i. Follow along with the student. If the student reads any word incorrectly or hesitates for 3 seconds tell the word to the student.
   b. For the next 3 iterations say to the student, “Thank you. When I say ‘Begin’ please read the same problem again exactly as before. If you have trouble with a word I will help you. Ready? Begin.”
      i. For each iteration follow along with the student. If the student reads any word incorrectly or hesitates for 3 seconds tell the word to the student.
   c. Circle any of the following phrases that appear in the problem, and explain how the phrase indicates the required operation. Feel free to model and use examples.
      i. “more than” – addition
      ii. “how many” and “in all” – addition
      iii. “how many” and “have left” – subtraction
      iv. “how many more (or fewer)” – subtraction
      v. “how much more” – subtraction
      vi. “the rest are” – subtraction
   d. Draw a picture of the problem. Since these are all problems that deal with joining, combining, comparing, or separating objects, the pictures should show the two different sets of objects given by the problem.
   e. Write out a mathematical statement. This just means to have the student write either one of the following:
      i. X + Y =
      ii. X – Y =
   f. Write the answer; in other words do the arithmetic.
5. When all of the problems are finished say to the student. “Thank you.”

Combined Strategy Mini-Probes

1. Select a blue mini-probe set, separate the two copies, and put one in front of the student face up.
2. Say to the student, “Now let’s see if you can solve some problems without my help. When I say ‘Begin’ please solve each of these problems. Remember to follow the same steps that we did with the worksheet: First read the problem 4 times out loud – I will help you if you get stuck, then circle the appropriate
phrase, then draw a picture, then write the addition or subtraction problem, and then solve the problem. When you finish a problem continue to the next problem. When you are finished with all of the problems turn your paper over or say ‘I am done’. Remember to read each problem 4 times out loud first.”


4. Start the stopwatch immediately after saying “Begin.”

5. For each problem follow along with the student while he or she reads the problem. If the student reads any word incorrectly or hesitates for 3 seconds tell the word to the student.

6. Also ensure that the student is following the strategy for each problem. If they are not then say, “Please remember to follow the steps that we practiced: [insert missing step].”

7. When the student indicates that he or she is finished, stop the stopwatch and say, “Thank you.” Record the time on top of the student’s mini-probe.
Appendix B

Treatment Integrity Checklist

Observer Name:_________________________ Date of Observation:____________________

Researcher Name:________________________ Student Participant ID:__________________

☐ Were the treatments administered in the correct block sequence for the day according to the schedule?

☐ Did the worksheets and mini-probes correspond to the correct color for each treatment (i.e., green for RR, yellow for math strategy, blue for combined, red for control)?

☐ Was each treatment cued correctly according to the script?

☐ Was the sequence of worksheet practice followed by mini-probe followed for each treatment?

☐ Was the worksheets portion of each treatment followed according to the script?

☐ Did the researcher ensure that the correct strategy was used by the student on each mini-probe?

☐ Were the mini-probes timed appropriately?

☐ Was the time recorded on the mini-probe completed by the child?

Total Number Checked:_______

Percentage Checked (Total Number Checked / 9 * 100%):_______

Comments:____________________________________________________________________
____________________________________________________________________________
____________________________________________________________________________
____________________________________________________________________________
____________________________________________________________________________
____________________________________________________________________________

Observer Signature:___________________________________ Date:____________________
Appendix C

Alternative Treatment Schedule

Please use the treatment sequence provided for each alternative treatment session. The sequence of the actual interventions was randomly selected, but with counterbalancing in mind.

Each of the participants will use the same schedule.

<table>
<thead>
<tr>
<th>Session</th>
<th>FIRST</th>
<th>SECOND</th>
<th>THIRD</th>
<th>FOURTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Session 1</td>
<td>Math Strategy</td>
<td>Combined</td>
<td>Repeated Reading</td>
<td>Control</td>
</tr>
<tr>
<td>Session 2</td>
<td>Combined</td>
<td>Control</td>
<td>Math Strategy</td>
<td>Repeated Reading</td>
</tr>
<tr>
<td>Session 3</td>
<td>Repeated Reading</td>
<td>Control</td>
<td>Combined</td>
<td>Math Strategy</td>
</tr>
<tr>
<td>Session 4</td>
<td>Combined</td>
<td>Repeated Reading</td>
<td>Math Strategy</td>
<td>Control</td>
</tr>
<tr>
<td>Session 5</td>
<td>Control</td>
<td>Math Strategy</td>
<td>Combined</td>
<td>Repeated Reading</td>
</tr>
<tr>
<td>Session 6</td>
<td>Combined</td>
<td>Math Strategy</td>
<td>Repeated Reading</td>
<td>Control</td>
</tr>
<tr>
<td>Session 7</td>
<td>Repeated Reading</td>
<td>Math Strategy</td>
<td>Control</td>
<td>Combined</td>
</tr>
<tr>
<td>Session 8</td>
<td>Combined</td>
<td>Repeated Reading</td>
<td>Control</td>
<td>Math Strategy</td>
</tr>
<tr>
<td>Session 9</td>
<td>Control</td>
<td>Repeated Reading</td>
<td>Math Strategy</td>
<td>Combined</td>
</tr>
<tr>
<td>Session 10</td>
<td>Math Strategy</td>
<td>Repeated Reading</td>
<td>Control</td>
<td>Combined</td>
</tr>
<tr>
<td>Session 11</td>
<td>Repeated Reading</td>
<td>Combined</td>
<td>Math Strategy</td>
<td>Control</td>
</tr>
<tr>
<td>Session 12</td>
<td>Control</td>
<td>Math</td>
<td>Repeated Reading</td>
<td>Combined</td>
</tr>
</tbody>
</table>
Appendix D
Sample Worksheet and Mini-Probe

The following are samples of the worksheet and mini-probe. The problem types, shown in Figure D.1 below are presented in a random order via a random number table.

<table>
<thead>
<tr>
<th>Problem type</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Addition</td>
<td></td>
</tr>
<tr>
<td>Joining</td>
<td>Jim learned to play 14 songs on the guitar. Joe learned 7 more than Jim. How many songs did Joe learn.</td>
</tr>
<tr>
<td>Combining</td>
<td>Adam had 8 clay animals. Carl made 16 clay animals. How many clay animals did they make in all?</td>
</tr>
<tr>
<td>Subtraction</td>
<td></td>
</tr>
<tr>
<td>Separate</td>
<td>Bill had 14 comic books. He let his friend have 7 comic books. How many does Bill have left?</td>
</tr>
<tr>
<td>Comparison</td>
<td>There are 5 pianos and 12 guitars in the music room. How many more (or how many fewer) guitars are there?</td>
</tr>
<tr>
<td>Joining missing addend</td>
<td>Carol has 32 cents. She wants to buy a brush that costs 69 cents. How much more money does Carol need?</td>
</tr>
<tr>
<td>Combining</td>
<td>The fourth-grade class has 20 students. 10 are girls and the rest are boys. How many are boys?</td>
</tr>
</tbody>
</table>

Figure D.1. Classes of problems to be used in the study. These problems were used in another study that employed the math strategy intervention (Case, Harris, & Graham, 1992).

Each worksheet and mini-probe will be printed on a colored piece of paper whereby each color corresponds to the treatment strategy to be used: control condition: red, repeated reading: green, math strategy: yellow, and combined strategy: blue. There will be 54 total worksheets and 54 mini-probes (1 for each of 4 conditions over 12 sessions plus 6 for the replication phase).
WORKSHEET: Repeated Reading

1. There are 7 trees and 3 bushes out in the yard. How many fewer bushes are there?

2. Jill has 10 candy bars. She gives 7 candy bars to her friend Bill. How many candy bars does Jill have left?

3. Greg’s class has 15 students. 5 are boys, and the rest are girls. How many students are girls?

4. John made 6 cookies. Jackie made 9 cookies. How many cookies did they make in all?

5. During a basketball game Jake made 8 baskets. Christy made 4 more baskets than Jake. How many baskets did Christy make?

6. Amanda bought 3 presents for her family. She needs to buy a total of 6 presents for all of her family. How many more presents does Amanda need to buy?
Mini-Probe: Repeated Reading

Student ID:__________________________________ Session Number:_____________________

Num Digits Correct:_________________________ Time to Complete:_____________________

1. Tracy read 3 books last month. Lindsey read 2 more books than Tracy did. How many books did Lindsey read?

2. There are 3 chairs and 2 couches in the family room. How many more chairs are there?

3. Jane has 7 dimes. She gives 4 dimes to her friend Jessica. How many dimes does Jane have left?

4. Mike found 5 insects. Ryan found 7 insects. How many insects did they find in all?
Appendix E

Student Participant Informed Assent Script

To Be Read Aloud to the Student

Hello [Child’s Name]!! My name is Mr. Brown, and I was informed that addition and subtraction math word problems may be difficult for you. I am very interested in trying to help you become better at finding the answers to these problems, and also helping you read better. Here is what would happen if you decide to let me help you. First, every day for a week, I will ask you to solve some word problems. This will just let me know where you are; this is not something that will be graded or shown to anybody else. Secondly, the two of us will get together 12 to 16 times for 50 minutes each, and I will show you different ways to solve problems. After we practice each way you’ll get to practice on some problems. One way would be just reading the problem out loud and solving it. Another way would be to read the problem out loud four times in a row with my help before you solve it. Another way will involve helping you to pick out important terms, and draw pictures to help you solve it. And still another way will be to read it out loud four times in a row and find key phrases and draw pictures. Remember: nothing you do will be graded at all; this is purely to see if this will help you ok?

If you would like to do this activity, then we will do what I described, and if you decide not to that’s ok too; nothing will happen if you don’t want to do this. Also you can always tell me to stop for any reason at any time. Also nothing that we do together will be graded and your name will not be on any of the work, so no one will know it was yours.

Would you like to let me try to help you by doing this activity?

Also is it ok if I talk to Mrs. Bergeron about your DIBELS activity? [If the child does not remember or know what that is then say:] Remember when you had to read for somebody with a stopwatch? Is it ok if I talk to Mrs. Bergeron about how you did then?

_Ideally the student must answer yes to both questions to participate, but even if the DIBELS data cannot be obtained, an affirmative answer to the participation question will be sufficient if enough students are not willing to participate._
Appendix F

Dear ____________:

Hello! My name is Dale Brown, and I am a graduate student at Miami University. I am in training to be a school psychologist, and I would like to extend to [child’s name] an invitation to participate in my research project.

[Child’s Name] is invited to participate in a study of how instruction in reading and math word problem solving influence students’ ability to solve simple, 1-step addition and subtraction word problems. If you choose to allow [Child’s Name] to participate, then [he/she] will participate in 12 to 16 instructional sessions during the school day lasting around an hour each. During each session we will teach [Child’s Name] how to practice 3 different ways to increase [his/her] word problem-solving ability. One way will involve reading the problem out loud 4 times in a row, and then solving it. This may seem strange, but it lets me know whether or not reading difficulties are hindering [Child’s Name] ability to solve the problem. The second way involves reading the problem, circling key terms in the text, drawing a picture, writing out the arithmetic statement, and then writing the answer. The third way is the same as the second except that [Child’s Name] would read the problem 4 times out loud before circling key terms. After instruction in each treatment [Child’s Name] will be asked to complete a short 4-problem probe to help me see how things are progressing.

[Child’s Name]’s name will not be associated with [his/her] work in any way. [Child’s Name]’s participation is voluntary and [he/she] may withdraw from any session, or even [his/her] total involvement, at any time or refuse to complete any tasks that make [him/her] uncomfortable. Likewise you are free to withdraw your child from any or all activities associated with this project at any time for any reason. There are no consequences for withdrawing. [Child’s Name] will not be asked to do anything that exposes [him/her] to risks beyond those of everyday life. The benefit of the study, scientifically, is it will help us understand more about the link between reading ability and math word problem-solving ability.

If you have further questions about the study, please contact Dale Brown at (260-417-5011, brownld@muohio.edu), or his thesis advisors Dr. Jane Cole (513-529-6629, coleje@muohio.edu), or Dr. Steuart Watson (513-529-0173, watsonts@muohio.edu). If you have questions about [Child’s Name]’s rights as a research participant, please call the Office of Advancement of Research and Scholarship at 529-3600 or email: humansubjects@muohio.edu.

Thank you for allowing [Child’s Name] to participate. We are very grateful for your help and hope that this will be an interesting and beneficial experience for [Child’s Name]. You may keep this page.

************************************************************************
Please detach and return this page. You may keep the first page.

I agree to allow [Child’s Name] to participate in the study of reading and math word problem solving. I understand [Child’s Name]’s participation is voluntary and that [his/her] name will not be associated with [his/her] work.

Parent’s signature ________________________________

Date ________________________________
References


