

Evaluation of the Relationship Between Literacy and Mathematics Skills As Assessed By Curriculum-Based Measures

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The purpose of this study was to evaluate the extent that reading performance (as measured by curriculum-based measures [CBM] of oral reading fluency [ORF] and Maze reading comprehension), is related to math performance (as measured by CBM math computation and applied math). Additionally, this study examined which of the two reading measures was a better predictor of applied math performance. Results of multiple hierarchical regression analyses indicated that math computation was the best predictor of applied math performance, followed by the Maze task. Also, results indicated that ORF did not significantly predict applied math test scores above and beyond math computation and Maze. Thus, from these results it appears that for fourth and fifth grade students, reading comprehension as measured by the Maze plays a more important role in predicting applied math performance than oral reading fluency.

While in school, deficiencies in mathematical competence have been found to seriously limit a student's educational opportunities (Hanich, Jordan, Kaplan, & Dick, 2001). Once out of school and employed, individuals proficient in math earn approximately 38% more than those who are not (Clarke & Shinn, 2004).

The National Council of Teachers of Mathematics (NCTM) set standards that delineate the goals for all students' math achievement (1989, 1991, 1995). These standards include five general math goals for children: to learn to value mathematics, to become confident in their ability to do mathematics, to become mathematical problem solvers, to learn to communicate mathematically, and to learn to reason mathematically (Foegen & Deno, 2001).

Despite these lofty goals, however, the actual math performance of students in the United States falls far short of expectations. In 1996, the National Assessment of Educational Performance (NAEP) published findings regarding student math performance. Only 21% of fourth graders were found to be at or above proficiency in math, while 36% of fourth graders fell in the below basic category of math performance. This pattern is similar for eighth and twelfth graders. Eighty percent of eighth graders could not solve modestly difficult problems, while only 16% of eighth graders had mastered the content of typical eighth grade math. Also, the NAEP indicated that only 8% of eighth graders could answer math questions requiring problem-solving skills (Clarke & Shinn, 2004; Thurber, Shinn, & Smolkowski, 2002).

Math Curriculum-Based Measurement

Most research of mathematics performance has supported a two factor model of mathematical assessment, the two factors being basic math computation and math application (Thurber et al., 2002). Computation is the ability to perform math facts, whereas application requires a person to use knowledge and math skills and apply them to word problems. These two components have been found to be distinct conceptually. As evidence of these two separate constructs, validity studies indicate measures typically conceived as measuring computation were correlated more highly with other computation measures and not correlated strongly with tools traditionally conceived as measures of math applications. The reverse was also found to be true (Thurber et al., 2002). These findings highlight the degree to which these two math components are distinct measures, however, the two types of math measures are also highly related.

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There is a degree of dependence among the math constructs, both applied and computation, indicating that the skills in one area are necessary for success in the other (Thurber et al., 2002).

Once students have begun explicit instruction in math, it is possible to identify students at risk for math academic problems through math computation and applied problem CBM measures (Clarke & Shinn, 2004). Math CBM appears to be a strong measure of individual and developmental differences with respect to math calculations skills (Hintze et al., 2002). Math CBM has reported interscorer agreement rates between .93 and .98 and internal consistency and test-retest reliabilities are about .93 (Clarke & Shinn, 2004). Alternate forms reliability has been reported from .66 to .91 (Thurber et al., 2002). Although there is limited research in this area, math CBM appears to be an un-biased predictor for students from diverse racial groups (Evans-Hampton, Skinner, Henington, Sims, & McDaniel, 2002).

Math CBM is also instructionally useful and acceptable. Students of teachers who found CBM highly acceptable and implemented the assessments with fidelity had greater growth slopes than students of teachers who did not use the progress monitoring with math CBM (Allinder, 1996; Allinder & Oats, 1997). However, it also appears that teachers need consultation support to help make appropriate revisions when progress monitoring with CBM. Without consultation support, students did not demonstrate as high of a level of outcomes (Fuchs et al., 1991). The conclusion can therefore be made that math CBM can be effectively utilized for instructional purposes that lead to improved outcomes when consultation assistance is provided.

Despite the areas of demonstrated success, more research with math CBM is necessary. As previously discussed, math is often thought of as a constellation of related, but not necessarily unified, constructs, skills, and content areas (Foegen & Deno, 2001). For example, research has indicated that peer-assisted learning strategies (PALS) promoted computational skills for students with disabilities, but not application skills (Calhoun & Fuchs, 2003). This would seem to indicate that perhaps there are other factors that affect applied math skills. Of these proposed skills, one thought to exert the largest influence on math performance is reading.

Reading Curriculum-Based Measurement

Reading has been defined as the decoding and comprehension of written text (Fewster & MacMillan, 2002). Of the existing CBM methods to assess reading components, two especially have demonstrated high levels of empirical validation. These measures are oral reading fluency (ORF) and the Maze cloze reading comprehension task (Faykus & McCurdy, 1998). Despite the fact that these tests are designed to assess different aspects of reading, performance on both reading tasks is highly correlated (Markell & Deno, 1997). Many studies indicate that oral reading fluency is a better predictor of reading comprehension than most reading comprehension tests are of each other (Shinn, Good, Knutson, Tilly, & Collins, 1992). In fact, oral reading fluency was found to be a better predictor of both total reading achievement and comprehension skills than the Maze, and was found to consistently correlate as high or higher with standardized measures of comprehension over any other alternative CBM measure, such as the Maze (Deno, Mirkin, & Chiang, 2004; Fuchs, Fuchs, & Maxwell, 1997). Further research has indicated that when conducting universal screenings, the Maze would not provide a significant amount of information regarding students' reading abilities beyond that explained by reading CBM (Ardoin et al., 2004). Thus, it appears the contribution of CBM ORF to the prediction of reading comprehension is significant and substantial, especially when compared to the Maze, which is specifically designed to measure reading comprehension (Kranzler et al., 1998).

The significant contribution of ORF to total reading achievement may be due in part to the strong technical qualities of ORF as a reading measure. Research has indicated an overall robustness for criterion validity, and strong developmental growth rates for the ORF as an index of proficiency (Fuchs & Deno, 1991). ORF shows the strongest criterion related validity with adequate construct and concurrent validity of all reading measures (Hintze et al., 1997). For reading CBM, the alternate form reliability typically exceeds .90. Test-retest reliability typically falls in the range of .82 - .97. The criterion validity typically falls in the range of .60 to .80 between ORF CBM and reading achievement tests (Hamilton & Shinn, 2003). In addition to the technical qualities, CBM oral reading rate was an effective metric for

use with students who were instructed in a literature based reading series (Bradley-Klug et al., 1998), and was found to not be biased by the curriculum used in the general education setting (Fuchs & Deno, 1991). Additionally, research has indicated that CBM ORF is not a biased predictor of reading for students from diverse racial groups (Hintze, Callahan, Matthews, Williams, & Tobin, 2002).

While the Maze task does have decent technical qualities, there is currently not as much research support for it as a reading comprehension measure. In fact, when compared to ORF, research has indicated that the Maze task may not be as sensitive in assessing growth over time as reading aloud (Shin et al., 2000) and in general ORF appears to be currently the strongest CBM reading measure.

Relationship Between Math and Reading

There is currently little research on the relationship between math and reading assessment tools. This is especially true for CBM measures, and the extent of the relationships between reading CBM and math CBM. Most of the research in this area tends to be focused on the comparison of four groups of students: students with math and reading difficulties, students with only math difficulties, students with only reading difficulties, and students that are normally achieving (Fuchs et al., 2004).

In general, students with challenges in both academic areas tend to perform lower on math assessments than students with difficulty in just one area (Fuchs et al., 2004). This is what one would expect. Students with math and reading difficulties are characterized by weaknesses in both problem solving and arithmetic fact mastery (Jordan, Hanich, & Kaplan, 2003). More importantly, deficits in both math and reading as early as second grade are pervasive and stable over the second and third grades, even when IQ is held constant (Jordan, Hanich, & Kaplan, 2003). It also appears that math computation difficulties may contribute more to math problem solving learning problems than do reading comprehension difficulties (Fuchs et al., 2004).

It appears that children with math deficits only should be considered separate from children with math and reading deficits (Hanich et al., 2001). To support this, research has demonstrated that children with math deficits only show a different pattern of cognitive deficits than do kids with both math and reading deficits (Jordan, Kaplan, & Hanich, 2002). Unlike students with both math and reading difficulties, children with math deficits only were strong on untimed conditions of math computation tests when compared to normally achieving students. However, this trend did not hold true on timed math computation tests (Jordan et al., 2003). As such, children with math difficulties only may have deficits associated with problem solving speed rather than with basic problem comprehension (Hanich et al., 2001). Another difference is students with deficits in math only appear to use counting strategies more effectively and have a better grasp of counting principles than students with math and reading deficits (Hanich et al., 2001).

Students with reading only deficits and students with deficits in both math and reading demonstrate academic progress at about the same rate in reading achievement (Jordan et al., 2003). Thus, it would appear that math abilities do not seem to have a significant influence on reading growth. Reading difficulties, regardless of specific or general nature, tend to remain stable (Jordan et al., 2002).

Math deficits, on the other hand, seem to be ameliorated by competence in reading (Jordan et al., 2003). It appears that some areas of math in particular, such as word problems and number combinations, may be mediated by language and reading due to the nature of the task (Jordan et al., 2002). Interestingly, in one recent study reading comprehension was highly correlated with both math computation, .69, and math applications, .76. In this study reading correlated to each measure of mathematics skill almost as much as the two math skills correlated to each other (.88), (Thurber et al., 2002). In addition to these high correlations, validity coefficients among math measures were improved when reading competence was included in a prediction equation (Thurber et al., 2002). To summarize, reading may be a necessary and important component in overall math competence and as such should not be overlooked when drawing conclusions about math skills (Thurber et al., 2002).

Research Questions

There is a clear need to provide educators tools necessary to better understand the performance of

students who struggle to acquire math skills. One technique that clearly can lead to improved student outcomes in math is progress monitoring (Fuchs, Fuchs, & Prentice, 2004) of students receiving intervention. Yet, to properly understand the outcomes of math assessment and specifically math progress monitoring, we need to clearly understand what is measured with math CBM tools. However, it appears that poor math performance is not necessarily solely an indication of math difficulties. Reading skill may be an important component of math skill, and as such it is difficult to say to what degree measures of mathematics are actually reflecting mathematical skills and weaknesses. It is therefore essential to understand the extent to which reading performance is related to math performance in order to gain a better understanding of what CBM math tests measure.

For the current study, two hypotheses were generated. First, applied mathematic assessments, such as the applied math CBM, could be measuring more than just mathematical skills due to the large amount of reading inherent in the problem types. As such, reading may influence performance on the applied mathematics test, and explain a significant amount of the variation in scores. Second, it would seem that reading comprehension would account for more variance in applied mathematics scores than reading fluency. However, based upon current research with reading CBM measures, ORF could possibly be a better predictor of applied mathematic performance, despite the fact that Maze was the CBM measure designed for assessing reading comprehension. Thus, two research questions are tested:

1. To what extent does reading, as measured by ORF and Maze, significantly predict performance on applied math performance, as measured by CBM applied math?
2. What measure more strongly predicts applied math performance, Maze or ORF?

METHODS

Participants and Setting

All student participants in this study were fourth (N=97) and fifth (N=83) grade students from one southern California urban elementary school. The total number of student participants was 180 students. Participants in this study were primarily instructed in the general education setting, with 11 (6%) receiving pull-out resource specialist program (RSP) services for up to 10 hours each week. One hundred two (53%) of the students participating in this study were female and 78 (43%) of the students were male. Of the 180 student participants, there were 126 (67%) Hispanic students, 22 (12%) Caucasian students, 20 (11%) African American students, 4 (2%) Filipino students, 4 (2%) Vietnamese students, 2 (1%) Korean students, and 1 (0.5%) Chinese student. Additionally, 83 (46%) of the students were classified as English language learners (ELL), with 3 (3%) of these students falling in the fluent/proficient range.

Materials

CBM oral reading probes. Three oral reading fluency (ORF) passages were obtained from AIM-SWeb (www.edformation.com), and were administered to each participant. These passages were written at grade level to be representative of the general curriculum for that grade. Standardized reading curriculum-based measurement (R-CBM) scoring procedures were utilized (Shinn, 1989), where participants are asked to read aloud from each passage for one minute. While the student read the passage aloud, the examiner scored the number of words read correctly. Words read correctly included words pronounced correctly in the given reading context and self-corrected errors that occurred within three seconds of the first attempt at the word. Words read incorrectly were words that were mispronounced, omitted, or substituted. Students were provided the word by the examiner if the student struggled or hesitated with a word for three seconds. This was also scored as an error. The ORF score used for analysis for each student was the median words read correctly score for the three reading probes.

The alternate form reliability for ORF typically exceeds .90. Test-retest reliability typically falls in the range of .82 - .97. The criterion validity typically falls in the range of .60 to .80 between ORF R-CBM and reading achievement tests (Hamilton & Shinn, 2003).

Maze reading comprehension probes. The curriculum-based measurement Maze (CBM-Maze) task

is a multiple-choice cloze task that students complete silently. One Maze reading comprehension passage was obtained from AIMSWeb (www.edformation.com) for each grade, fourth and fifth. This assessment was constructed using the procedures described by Parker, Hasbrouck, and Tindal (1992). As such, the first sentence of the passage is left intact. Thereafter, every seventh word was replaced with a set of three words in parentheses. One of the three words is the exact word from the original story, while the other two words are distracters that were incorrect in the context of the story. One of the distracters is a word that is the same part of speech as the correct, original word, however does not preserve the meaning of the text or makes no sense. The other distracter is a randomly selected word that makes no sense in the context of the passage. The Maze score used for analysis was the percent of words correctly selected from the passage.

CBM-Maze passages demonstrate acceptable technical quality. Criterion related validity correlations with ORF are reported to fall between .80 and .89 (Fuchs & Fuchs, 1992; Jenkins & Jewell, 1993). Additionally, criterion related validity with other published, norm-referenced tests of reading comprehension, such as the Stanford Achievement Test-Reading Comprehension subtest, is reported to fall between .77 and .85 (Fuchs & Fuchs, 1992). The test-retest reliability over a one month period is reported as .83 (Shin, Deno, & Espin, 2000).

Basic mathematics computation. Two basic math computation probes, one for each grade both fourth and fifth, were selected from the Monitoring Basic Skills Progress – Second edition and used in this study (Fuchs, Hamlett, & Fuchs, 1990). Each test is designed to represent and measure the math computation curriculum for the entire year, and as such, within each grade level, the types of problems presented on each test are constant. However, the exact numbers used and the position of each problem (e.g. first, third, etc.) are randomly presented on each test. For the fourth and fifth grade levels, the types of problems presented are division of whole numbers, multiplication, decimals, and fractions. Each test has 25 math computation problems. The scores used for analysis were the total number of correct digits for each probe. This is calculated by simply adding the number of correct digits for each answer, and summing them for the grand total for the probe. As such, it is possible to receive partial credit for an answer that is only part correct.

The internal consistency for both the fourth and fifth grade probes on the basic math computation test is .97. Criterion validity for the basic math computation probes was established based on correlations to the California Tests of Basic Skills (CTBS) computation subtest scores. The correlation between the CTBS-computation subtest and the basic math computation scores was .74 for fourth grade, and .67 for fifth grade (Fuchs et al., 1990).

Basic mathematics concepts and applications. Four basic math concepts and applications probes, two for each grade both fourth and fifth, were selected from the Monitoring Basic Skills Progress – Second edition and used in this study (Fuchs et al., 1990). Each test is designed to represent and measure the math concept and application curriculum for the entire year, and as such, within each grade level, the types of problems presented on each test are constant. There are between 18 and 25 questions on each probe. The skills assessed on each probe include number concepts, measurement, names of numbers and vocabulary, grid reading, charts and graphs, decimals, fractions, word problems, and geometry. Again, the scores used for analysis were the total number of correct digits for each probe. The internal consistency for both the fourth and fifth grade probes on the basic math concept and application tests is .97. Criterion validity for the basic math concept and application probes was established based on correlations to the California Tests of Basic Skills (CTBS) subtest scores. The correlation between the CTBS subtest and the basic math concept and application scores was .75 for fourth grade, and .81 for fifth grade (Fuchs et al., 1990).

Procedures

Four graduate level students enrolled in a doctoral-level school psychology program at a major Pacific Southwestern university were trained to administer and score all assessment materials. Each graduate student successfully completed three graduate level courses in test assessment and scoring

procedures. Additionally, each data collector was given a set of standardized instructions for each assessment given.

Administration procedures. All tests (CBM-Maze, basic math computation, and basic math concepts and applications) were administered to groups of participants in their classrooms, except for ORF R-CBM. The ORF probes were individually administered at a quiet location outside of the classroom. Two data collectors went to each classroom, and took turns either reading the directions for the test to the class or distributing, collecting, and proctoring the tests. The group assessments were administered first to each class, and took approximately 15 to 20 minutes to complete. The accommodated and non-accommodated applied math tests were given first, in a counterbalanced order, followed by the computation math test, then the Maze task. Following the group administrations, students were pulled out one at a time for the individually administered ORF probes. This took approximately four minutes per student. The present study was a part of a larger accommodation study, however the current study will not utilize the scores for the accommodated basic math concepts and applications test. However, as part of the larger study, both the order of administration for the accommodated and non-accommodated math concepts and applications tests and the specific test, out of the two per grade level, that was accommodated for each grade was counterbalanced to control for both order and probe effects.

As previously stated, standardized administration protocols were developed to administer the three group-administered assessments. Again, testing began with either the accommodated or non-accommodated applied math test given in the classroom in group format. The second group test administered was the second applied math test, either accommodated, if previously given the non-accommodated, or non-accommodated, if previously given the accommodated version. After the group administered applied math tests, the participants were then given the computational math test. Fourth, the students were given the Maze also in a group administered format. Last, the participants were individually administered the ORF reading task at a quiet location outside of the classroom.

The precise standardized administration protocols for the CBM-Maze test and the ORF test can be found on AIMSWeb (www.edformation.com), along with the probes and alternate forms of the probes. For the computation math test, students were given the probe and then told by the examiner, “We are going to do some more math. Please write your name on the paper. I want you to do as many problems as you can. Work carefully and do the best you can. When I say begin, start at the top left, working from left to right. Keep working until I say stop. Do you have any questions? Begin.” Students were then given five minutes to work on the test. At the end of five minutes, the examiner said, “Stop,” and the tests were collected.

The administration protocol for the application math test with accommodation began with the examiner passing out the test. The examiner then said, “As soon as I give you your test, write your first name, your last name, and the date. I want you to do as many problems as you can. Remember, start at the first problem, work down the first column, and then the second column. Then move on to the next page. When you come to a problem you know you can do, do it right away. When you come to a problem that is hard for you, skip it and come back to it later. When I say begin, start to work. Work for the whole test time. Write your answers so I can read them. If you finish early, check your answers. At the end of five minutes, I will tell you to stop and put your pencils down. Are there any questions?” Following this, the examiner then said, “Before we begin, I will read the questions on the test aloud to you. Please follow along with me on your test.” The examiner then read the questions on the test aloud, with the entire class following along. After reading the questions, the examiner then instructed the students to begin. Participants were given five minutes to work on the test, and then were told to stop, and the test was collected. The administered protocol for the application math test without accommodation was exactly the same, except the questions were not read aloud, neither were the directions regarding reading the questions aloud. As previously indicated, the current study will not utilize the scores for the accommodated basic math concepts and applications test.

RESULTS

Descriptive Statistics and Correlational Analysis

The means and standard deviations for the two reading measures, ORF (oral reading fluency, words read correctly per minute) and Maze (reading comprehension task, percent correct words selected in three minutes), and two math measures, basic math computation (Computation, CM, digits correct in five minutes on basic math skills probe) and basic math concepts and applications (Applied, AM, digits correct in five minutes on math concepts and applications probe) are presented in Table 1.

TABLE 1: *Descriptive Statistics for All Predictor and Outcome Variables*

<i>Source</i>	<i>N</i>	<i>M</i>	<i>SD</i>
Maze	180	77.85	22.78
ORF	178	107.57	38.77
Computation	180	36.35	24.52
Applied	179	7.63	4.74

Pearson correlations among the four measures included in the analyses are presented in Table 2. The correlations between ORF and Maze, ORF and CM, ORF and AM, Maze and AM, and CM and AM were all statistically significant ($p < .01$). The correlation between Maze and CM was also statistically significant ($p < .05$). A significant, large correlation (as determined by Cohen, 1988) is shown between ORF and Maze. A significant, moderate correlation (Cohen, 1988) is shown between ORF and CM, ORF and AM, Maze and AM, and CM and AM. Finally, a significant, small correlation (Cohen, 1988) is shown between Maze and CM.

TABLE 2: *Correlation Matrix Between Predictor Variables and Outcome Variable*

<i>Source</i>	<i>ORF</i>	<i>MAZE</i>	<i>Computation</i>	<i>Applied</i>
ORF	1.00			
MAZE	0.57**	1.00		
Computation	0.34**	0.18*	1.00	
Applied	0.37**	0.36**	0.35**	1.00

Note. $N = 180$. * $p < .05$; ** $p < .01$

Regression Analysis

The two aims of this study were explored by conducting multiple hierarchical regression analyses. Hierarchical regression analysis is an approach that allows one to determine unique variance attributable to a particular variable, after controlling for the effects of covariates (Myers & Well, 2003). In all of the analyses, the criterion variable of applied math (AM) was regressed on ORF, Maze, and computation math (CM) in order to determine their predictive value.

Prediction of applied math performance by ORF vs. Maze. The first hierarchical regression consisted of entering CM on the first step, followed by entering Maze on the second step, and ORF on the third. This was done to assess for the unique variance explained by ORF. The second hierarchical regression involved entering CM first, ORF second, and Maze last. This was done to allow for the determination of the independent contribution of Maze to predict AM. The third hierarchical analysis consisted of entering ORF and Maze on the first step, followed by entering CM on the second step. This was done to control for the combined effects of ORF and Maze on AM.

Results from the multiple hierarchical regression analyses are delineated in Table 3. The first hierarchical regression analysis was performed to look at the unique effect of ORF on AM after controlling for individual performance on CM and Maze. Results from this analysis indicate that controlling for the effect of CM, Maze was able to predict AM above and beyond that of CM. However, when controlling for the effects of CM and Maze, ORF was not able to independently contribute to the prediction of AM. As Table 3 displays, CM, Maze, and ORF individually accounted 13%, 9%, and 1% of AM variance respectively.

TABLE 3: Hierarchical Regression Analyses Predicting Applied Mathematics

	Summary Statistics			
Source	<i>Df</i>	β	<i>t</i>	ΔR^2
First Hierarchical Regression Analysis				
Step 1: Computation math	1, 175	.26	3.66**	.13**
Step 2: Maze	2, 174	.23	2.79**	.09**
Step 3: ORF	3, 173	.15	1.80	.01
Second Hierarchical Regression Analysis				
Step 1: Computation math	1, 175	.26	3.66**	.13**
Step 2: ORF	2, 174	.15	1.80	.07**
Step 3: Maze	3, 173	.23	2.79**	.04**
Third Hierarchical Regression Analysis				
Step 1: ORF and Maze	2, 174	Maze: .23 ORF: .15	Maze: 2.79** ORF: 1.80	.17**
Step 2: Computation math	3, 173	.26	3.66**	.06**

* $p < .05$; ** $p < .01$

The second hierarchical regression analysis looked at the ability of Maze to uniquely contribute to the model after holding constant the effects of CM and ORF. Results revealed that when holding CM constant, ORF was able to significantly predict AM. Unlike the prior analysis, however, when controlling for the effects of CM and ORF, Maze was still able to explain a significant amount of variance in AM. In this, CM, ORF, and Maze significantly accounted for 13%, 7%, and 4% of the AM variance respectively. Thus, it would appear that Maze adds additional prediction of one's applied math performance than ORF because Maze significantly contributed to the prediction of AM after holding ORF and CM constant. This did not hold true when ORF was entered last into the model.

Prediction of applied math performance by reading measures and math computation. The final hierarchical regression analysis assessed the unique predictive power of CM subsequent to holding the combined effects of the reading measures, ORF and Maze, constant. ORF and Maze significantly accounted for 17% of the variance in AM, with CM individually accounting for another 6% of the AM variance. The results suggested that when controlling for the reading measures, ORF and Maze, CM was able to significantly predict AM. In light of these results, it appears that basic math skills computation is the strongest overall predictor of applied math performance. Thus, the results indicate that measures of one's basic math skills computation and reading comprehension are more useful indicators of how one is likely to perform on an applied math assessment, relative to one's reading fluency.

DISCUSSION

The main purpose of the study was to investigate the extent to which reading performance, as measured by CBM oral reading fluency and Maze reading comprehension, is related to math performance, as measured by CBM math computation and applied math. Two hypotheses were tested: 1) Does reading, as measured by ORF and Maze, significantly predict performance on applied math performance, as measured by CBM applied math? 2) Given that ORF currently has stronger empirical support as a comprehension measure, does ORF predict performance on applied math better than the Maze?

Predictive Ability of Reading, ORF and Maze, and math Computation on Applied math Outcomes

The ability of reading comprehension, as measured by Maze, to predict applied math performance was consistent with previous research. Thus, the results of this study provide further evidence of the importance of reading comprehension on applied mathematics assessment (Jordan et al., 2003; Jordan et al., 2002; Thurber et al., 2002). This is important for several reasons. First, this indicates that applied math tests are not solely measuring math skill. As such, it is possible for a child to be proficient in math, but perform poorly on an applied math assessment if they have poor reading comprehension. Thus, it would be an incomplete assessment to give a student an applied math test as the only measure of math skill. This finding is also important because it can help with math intervention development. It is possible that a reading comprehension intervention can increase performance on applied mathematics tests. Thus, if a student who needs intervention is demonstrating weaknesses in both reading and math, one approach would be to focus on reading interventions first, as reading demonstrates significant effects in both areas.

The finding that math computation was the best predictor of applied math performance is also consistent with previous research (Fuchs et al., 2004). As such, the results of this study verify that basic math skills predict performance on applied math tests. This is important for several reasons. First, it provides a degree of criterion validity support for applied math tests as math assessments, since math computational skill best predicts, and is highly correlated, to the applied math tests. This can be extended as further evidence for math CBM measure criterion validity.

That basic math skills are better predictors of applied math performance than reading comprehension skills is also important for intervention planning. As such, if a child demonstrates greater weakness in basic math skill performance than in reading performance, an intervention would produce greater gains by addressing the poor computation skill performance. Additionally, math computation CBM is an appropriate progress monitoring tool for a math intervention. As such, math computation CBM gains would also indicate gains in applied math CBM.

Predictive Ability of ORF versus Maze on Applied math outcomes

Unlike previous research, the results of this study indicated that Maze was a better predictor of applied math performance than ORF. This seems to be more intuitive, however is counter to most research (Ardoin et al., 2004; Jenkins & Jewell, 1993). Further analysis of the discrepancy between previous research and the findings of this study, however, highlight several interesting findings. First, in the study by Ardoin et al. (2004), sample size was an issue. The authors discussed the possibility that the sample size was insufficient to allow strong conclusions from tests of individual predictors. As such, they suggested the results of the multiple regression analyses that were conducted should be examined and interpreted with caution. Additionally, participants in the Ardoin et al. study were all third graders. As will be addressed more completely later, it is possible that age or grade play a large role. A third major difference is that approximately 44% of the sample were of an ethnic minority, while the current study had approximately 88% of the sample representing an ethnic minority. Although most math CBM research indicates the measure is unbiased, it is possible that ethnicity plays a role in the test's relationship with other variables. A fourth, and perhaps more important, difference between this and previous research is that few previous research studies used the Maze task to measure reading comprehension. As such, it is possible that Maze is a better indicator of reading comprehension than previous research has postulated.

As previously stated, one of the differences between the study by Ardoin et al. (2004) and the current study was the grade of the students participating. In their study, third graders were the participants, while the current study looked at fourth and fifth graders. This brings up an interesting finding from the research by Jenkins and Jewell (1993). While Jenkins and Jewell (1993) also found ORF to correlate more highly to comprehension measures than the Maze, they also noted that this correlation declined in older grades. Thus, while ORF correlated more highly to reading comprehension achievement test scores than the Maze for the second graders in the study, this correlation declined linearly by sixth grade, whereas the correlation between the Maze and tests of reading comprehension achievement did not demonstrate this decline. Jenkins and Jewell (1993) proposed that this is possibly due to the fact that as students progress through school, reading becomes less focused on decoding and fluency and more focused on comprehension. Thus, "reading comprehension" standard achievement measures for second graders are more focused on fluency and decoding, which is what ORF is designed to measure, while the reading comprehension measures of fourth, fifth, and sixth graders are more focused on actually understanding and learning from text. The results of this study provide further support for this possibility. However, further research is necessary in this area.

General Conclusions

Overall, math computation skills and reading comprehension skills predict a significant amount of the variance in applied mathematic performance. As discussed, this has important implications for the reliability and validity of CBM measures in these areas. Additionally, this knowledge is extremely helpful in designing academic interventions. It is thus important to keep in mind when intervening with students with math difficulties that reading influences applied math skills. As such, it is important to make the distinction between students that have difficulty only with math versus students that have difficulty with both math and reading. It is possible for a reading intervention to have collateral effects and also increase math performance. Thus, when intervening with children that demonstrate deficits in both reading and math, reading intervention may warrant consideration as the first step.

The results of this study also have important implications for math and reading curriculum in general. Since reading comprehension skills affect applied math performance, it is perhaps prudent to spend more classroom instructional time working on developing strong reading skills, especially in the early grades when reading difficulties can be more easily remediated.

Limitations and Future Research

As with any research study, there were limitations with the current study. First, despite the significance of the predictors, math computation and Maze still only accounted for approximately 22% of the

variance on applied math tests. This leaves an approximate 78% of the variance unaccounted for. It is possible that there is another factor that predicts applied math performance better than math computation or math computation and Maze together. Further information in this area could be beneficial to improving math interventions.

As discussed previously to some degree, this study only looked at fourth and fifth graders. Based on previous research in the area of the relationship between reading and math, it would be prudent to look at a wider range of grades, with a sufficient n, to see if the difference between ORF and Maze as predictors does indeed change as a function of grade.

Lastly, the sample of the current study was composed of mostly minority students. As such, the results may not be generalizable to populations that are less diverse, although there is little evidence to suggest CBM measures predict differentially by race or ethnicity.

In sum, the present study both extended and challenged the findings of previous research focusing on the relationship between math and reading performance, and the predictive ability of ORF versus the Maze task. The bottom line is that while math computation scores are the best predictors of applied math performance, reading comprehension also independently contributes significantly to the prediction. Reading comprehension as measured by Maze plays an important role in applied mathematics performance. In this study, ORF did not contribute any unique information to prediction of applied math performance beyond that accounted for by Maze. It may be that Maze is a better method of assessing reading comprehension for grades four and up, especially in relation to math performance.

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