Learning and Individual Differences 43 (2015) 118–123

Contents lists available at ScienceDirect

Learning and Individual Differences

journal homepage: www.elsevier.com/locate/lindif

Differences in the reading–mathematics relationship: A multi-grade, multi-year statewide examination☆

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ARTICLE INFO

Article history:
Received 20 February 2014
Received in revised form 16 June 2015
Accepted 13 August 2015

Keywords:
Reading achievement
Mathematics achievement
State assessment
Hierarchical linear modeling
Structural equation modeling

ABSTRACT

In this study, we explored the relationship between mathematics and reading achievement using statewide assessment data from all students (Grades 3–11) in multiple years to examine how that relationship differs based on student, school, and district characteristics. In modeling this relationship, the researchers found that although reading and mathematics ability explain a significant amount of variability in an individual year's achievement, there is substantial variability remaining to be explained beyond that, particularly at the middle school and high school levels. Thus, the need to look at individual characteristics is strongly warranted. The results indicated that reading and mathematics achievement were positively related at the student level and more strongly at the school level, but the relationship was not as strong among females and non-White students.

1. Introduction

Reading ability is key for both educational progress and achievement. However, approximately 40% of children in the U.S. struggle with reading (Walsh, Glaser, & Wilcox, 2006). Reading difficulties at young ages can affect adolescents and adults (Lundetrae, Gabrielsen, & Mykletun, 2010) in both their educational attainment and achievement level and their employment (Bynner & Parsons, 2001; Carnevale, 2001; Kamil, 2003; Lundetrae et al., 2010; Rychen & Salganik, 2003; Snow & Biancarosa, 2003). Moreover, a student's literacy ability has important consequences for achievement in other content areas, including mathematics. Although the relationship between reading and mathematics has been well established (Babaresi, Katusic, Colligan, Weaver, & Jacobsen, 2005; Fuchs et al., 2006; Hooper, Roberts, Sideris, Burchinal, & Zeisel, 2010; Jordan, Hanich, & Kaplan, 2003; Lewis & Mayer, 1987), very little is known about how that relationship may differ across subgroups. In this study, we examined patterns in the mathematics-reading relationship and how individual student background characteristics, school characteristics, and district characteristics moderated that relationship. We used statewide data across all assessed grades (3–8 and high school) and across multiple years and were able to link students, schools and districts, thus giving a very broad and comprehensive examination of what individual as well as organizational characteristics might be related to the connection between mathematics and reading.

1.1. The relationship between reading and mathematics achievement

In the American education system, there exists a strong emphasis on reading as literacy skills have been substantiated as critical for overall academic success. Students' literacy has important consequences for achievement in other content areas, including the development of mathematics skills and achievement. Students who have difficulty in reading have a high likelihood of experiencing difficulty in mathematics (Babaresi et al., 2005). Researchers have found that these two content areas are related as early as preschool (Duncan et al., 2007; McClelland et al., 2007; Purpura, Hume, Sims, & Lonigan, 2011; Welsh, Nix, Blair, Bierman, & Nelson, 2010). Studies have reported correlations between various reading and mathematics skills as moderate to high (Fuchs et al., 2006; Hecht, Torgesen, Wagner, & Rashotte, 2001; Purpura et al., 2011; Swanson & Beebe-Frankenberger, 2004). Reading and mathematics skills have been documented as being related over time, as early as kindergarten and as late as high school (Duncan et al., 2007; Hooper et al., 2010). In Kentucky, researchers have found moderate, positive correlations between the state assessment reading and mathematics scores at the high school level (Bacci, Koger, Hoffman, & Thacker, 2003).

☆ This research was supported in part by a grant from the Collaborative Center for Literacy Development (CCLD). The findings and opinions expressed here do not necessarily reflect the position or policies of CCLD.
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http://dx.doi.org/10.1016/j.lindif.2015.08.006
1041-6080/

Many studies have documented that skills in each content area influence the development of skills in the others (Fuchs, Fuchs, & Prentice, 2004; Jordan, Kaplan, Olah, & Locuniak, 2006). Specifically, in mathematics the ability to decipher and comprehend language used in mathematical problems connects to a student's ability to solve such problems (Lewis & Mayer, 1987). Students who fail to comprehend what a mathematics problem is asking them to do might fail to apply a computational technique that they have otherwise mastered. The wording and structure of mathematics word problems affects students' ability to comprehend and ultimately solve the problems (Clarkson & Williams, 1994). Perhaps as a result, students who experience both reading and mathematics difficulties often develop mathematics skills at slower rates compared to students who experience difficulties in mathematics only Jordan et al., 2003).

Potential contributions to the significant relationship between reading and mathematics achievement have been attributed to genetics, general cognitive ability, and environmental influences (Hart, Petrill, Thompson, & Plomin, 2009). However, the specific nature of the relationship between reading and mathematics across subgroups remains unclear, and much is to be learned. The aspects we take into consideration in the current study are several that have not been widely researched in the literature: the interaction effect of reading achievement and student, school, and district characteristics on mathematics achievement within grade levels and across years.

1.2. The current study

In the current study, we examined moderators of the reading-mathematics relationship in Kentucky, considering individual student background characteristics as well as school and district characteristics. The Kentucky Department of Education (KDE) collects statewide data at the student, school, and district levels and maintains identifiers connecting these three levels. Therefore, we were able to examine patterns across each tested grade level and across multiple years and could examine cross-level relationships (i.e., the relationship between school and district variables and the interaction between student mathematics and reading achievement). The purpose of this study was to examine the relationship between reading achievement and mathematics achievement and, more importantly, examine the patterns of moderating effects on that relationship (i.e., what student, school, and district characteristics consistently moderate the relationships across multiple grades and years).

2. Materials and methods

2.1. Participants

We analyzed data provided by the KDE Office of Assessment and Accountability and for all students in public, non-alternative schools who took the Kentucky Core Content Test (KCCT). Tested grade levels were 3 through 8 for both subjects, 10 for reading, and 11 for mathematics. Because we were interested in patterns that might indicate individual differences, we looked for trends versus cohort effects using data from 2007 to 2010.

Average sample sizes per year for elementary school (Grades 3–5), middle school (Grades 6–8), and high school (Grades 10 and11) were 41,613, 40,981, and 41,731, respectively. There was an average of 635 elementary schools, 314 middle schools, and 214 high schools per year. Those schools were in an average of 159, 157, and 145 districts, respectively.

In the assessed grades, averaged across 2007 to 2010, Kentucky had nearly equivalent proportions of male and female students (48.7% to 49.2% female). The majority of students (82.5% to 86.8%) were White, with 10.0 to 10.7% of students identifying as Black, 2.0% to 3.2% identifying as Hispanic, 1.0% to 1.3% identifying as Asian, and 1.5% to 2.2% identifying as Other. The percent of students receiving free- or reduced-price lunch decreased slightly over the grade levels, ranging from 55.5% (third grade) to 46.7% (high school). The percent of students with an individual education plan (IEP) and identified as English Language Learners (ELL) also decreased over the grade levels, ranging from 9.5% to 15.3% for IEP and 1.0 to 2.5% for ELL.

Just as the percent of students receiving free- or reduced-price lunch across the sample decreased slightly over the grade levels, so did the school percent free- or reduced-price lunch, ranging from 57.0 to 65.4%. The percent of Title I schools ranged from 72.0 to 89.0%. The schools were primarily White, averaging 10.0 to 15.2% non-White. Grades 3 through 5 all had school enrollments in that grade of about 445 students, while grades 6 through 8 ranged from an average of 486 to 533 students and high school had about 886 students in a grade level.

The districts were primarily White, with an average of 8.7 to 13.0% non-White. The districts had similar percentages of students receiving free- or reduced-price lunch (61.3 to 62.4%). District enrollment at each grade level ranged from 3934 to 4118, on average.

2.2. Measures

2.2.1. Outcome

We examined the relationship between KCCT reading and mathematics scores, which are reported on a scale ranging from 0 to 80 scales. Table 1 presents the average achievement scores for the current and previous year for both reading and mathematics. The KCCT was used for state and federal accountability purposes but is not used for student-level decision making. It included both selected- and open-response items, and was subject to several validation studies (e.g., Kentucky Department of Education (KDE), 2007; Sinclair, Thacker, Koger, & Dickinson, 2008). The test scores have exhibited adequate reliability, with alphas ranging from .87 to .90 for reading and .86 to .90 for mathematics for the 2007 KCCT (Kentucky Department of Education (KDE), 2007).

2.2.2. Moderating variables

KDE provided all demographic data on each assessed student, school, and district. Table 2 includes the moderator variables at each level and their coding.

2.3. Analyses

These data violated the assumption of independence of observations that most traditional statistics make as students were nested within schools and schools were nested within districts. Additionally, we were interested in examining the interactions among variables that occur at multiple levels (i.e., student, school, and district level). As recommended by McCoach and Adelson (2010), we used hierarchical linear modeling (HLM) to account for the clustered data and appropriately model the predictors at multiple levels.

To test the relationship between reading and mathematics achievement, mathematics achievement was the outcome variable. We included the prior years' mathematics achievement as a control variable and included statistically significant student, school, and district characteristics as predictors of mathematics achievement to appropriately model the intercept. Then, we added reading achievement scores to the model to determine what proportion of the variability in mathematics achievement was explained by reading achievement, above and beyond prior mathematics achievement and student, school, and district characteristics. Then, to examine the moderators of that relationship, we tested interactions with reading achievement to see if the variables at any of the three levels (e.g., gender, non-White, Title I school) moderated the relationship between reading and mathematics achievement.

In building our models, we used three-level HLMs, with students nested in schools nested in districts, and we used a general analytic strategy that followed the guidelines suggested by Raudenbush and Bryk (2002). We built the models separately for each grade level and