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Exploring the Role of Social Reasoning and Self-Efficacy in the Mathematics Problem-Solving Performance of Lower- and Higher-Income Children

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Research documents an income-based achievement gap in mathematics, yet children from lower-income backgrounds do not lag behind their more advantaged peers in high-level social reasoning tasks. The purpose here was to investigate whether modifying mathematics word problems to make them more socially based would impact the mathematics performance and/or mathematics self-efficacy of lower- versus higher-income children. Research questions regarding (1) the relative difficulty of symbolic equations versus word problems, (2) the impact of socially modifying word problems on children's accuracy and self-efficacy, and (3) the relation between children's mathematics performance and mathematics self-efficacy were explored. Participants were 164 5th graders. Children completed a mathematics problem-solving test comprised of multiplication problems representing four different problem formats (two social, two abstract). Three types were word problems, and one was a symbolic (abstract) presentation. The three word problem types were everyday activity (social), social-cognitive (social), and traditional textbook (abstract). Participants also completed a mathematics self-efficacy measure. Children performed better on symbolic problems than on any of three word problem types. The lower-income group performed better on innovative social-cognitive word problems than on decontextualized word problems. Word problem variations did not have an effect for the higher-income group. Overall, mathematics self-efficacy was shown to predict mathematics performance. While problem format is only one aspect of a highly complex instructional system, findings suggest that capitalizing on social-cognitive strengths in mathematics may be valuable for improving the academic achievement of lower-income children.

Keywords: *achievement gap, mathematics problem-solving, self-efficacy, social cognitive theory*

Introduction

Many argue that "mathematical competence opens doors to productive futures" (National Council of Teachers of Mathematics, 2000, p. 1). Indeed, mathematical knowledge may serve a gatekeeping function, with successful mathematics students receiving greater career choice, occupational status, and pay (Campbell, 1989; Lubienski, 2000). Unfortunately, research consistently documents children from economically disadvantaged families exhibiting lower levels of mathematics achievement than more affluent children (Lee & Burkam, 2002; Phillips, Brooks-Gunn, Duncan, Klebanov, & Crane, 1998). Data from the National Assessment of Educational Progress also support the notion that the poor math performance of low-income children is an enduring concern (National Center for Education Statistics [NCES], 2011). While National Assessment of Educational Progress data reveal that average mathematics scores were higher in 2011 than in any previous assessment year, the achievement gap between low- and middle-income students persists (NCES, 2011).

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Undoubtedly, considering the influence of sociocultural differences among children is critical as we seek to understand children's success and failure in mathematics problem-solving and strive for educational equity (Boaler, 2002; Cooper & Dunne, 2000; Lubienski, 2002). Arnold and Doctoroff (2003) acknowledge the need to "utilize and build [low-income] children's strengths" and encourage future researchers to conduct experimental studies that examine cultural factors in children's education (p. 517). The present study addresses this call and offers a "strengths-based" view of the cognitive development and educational experiences of children from lower-income backgrounds. Specifically, this research seeks to capitalize on the particular social-cognitive strengths that some low-income children may develop as a function of their socialization experiences.

Lubienski (2002) proposes that the goal of sociocultural studies should be to learn how to implement meaningful instructional methods equitably with students who differ in terms of social class so that "particular practices that appear promising for particular groups of students" can be identified (p. 121). The purpose of this research was to investigate whether providing a social context for math problems leads to more accurate performance than nonsocial (abstract) problem formats for children from lower- and higher-income backgrounds.

An extensive array of social cognitive skills emerges in early childhood. For example, Dunn (2002) showed that young children routinely engage in sophisticated social interactions including cooperation, telling jokes, deception, and sharing. Further, young children tend to acquire the knowledge structures used to interpret the sociocultural world fairly easily, as seen in young children's representations for events (Nelson, 1986) and narrative (Bruner & Lucariello, 1989; Peterson & McCabe, 1991). Young children also develop an understanding of persons as psychological beings who have unique emotions, beliefs, and perceptions. This high-level cognitive skill is termed "theory of mind" (ToM), and it entails our imputation of mental states to the self and others to account for behavior (Astington, Harris, & Olson 1988).

While lower-income children are often surpassed by more economically advantaged children on a variety of cognitive and academic tasks (Noble, Norman, & Farah, 2005), findings suggest that lower-income children may be less vulnerable with respect to social cognitive skills. Notably, no income-based performance gap is observed on tasks assessing social ToM, which entails reasoning about others' (versus one's own) mental states (Lucariello, Durand, & Yarnell, 2007; Lucariello, Le Donne, Durand, & Yarnell, 2006).

Particular strength in social reasoning for lower-income children could be a function of their socialization experiences. While there may be many socialization experiences that orient children to the social world, two of the principal aspects that may promote social-cognitive strengths for lower-income children are the development of an interdependent self-concept (Greenfield, 1994; Markus & Kitayama, 1991) and discourse practices that are socially oriented (Brice Heath, 1983; Miller, Cho & Bracey, 2005).

An interdependent self-concept places great importance on relatedness to others (Markus & Kitayama, 1991). People who possess an interdependent self-concept view their primary tasks as fitting into their social group, promoting others' goals, and reading others' minds (Markus & Kitayama, 1991). Cognitively, Markus and Kitayama (1991) assert that children who are socialized into an interdependent self-concept may experience heightened sensitivity to information that is relevant to others and may be more attentive to others in general.

In addition to an interdependent self-concept, research suggests that an "interpersonal-pragmatic" model of language use may be common in lower-income communities. For example, longitudinal research by Blake (1993, 1994) on communication between three urban working-class mothers and their children classified mothers' language use as having a social-emotional orientation. In addition, socially based discourse practices such as personal storytelling and teasing may be common aspects of socialization in lower-income families (Miller, 1986; Miller et al., 2005). Teasing serves important social functions and reflects the "high value placed on interpersonal skills" such as "self-assertion and self-defense" in working class families (Miller, 1986, p. 200). Highly developed skill in personal storytelling serves important social goals and needs, such as negotiating peer relations (Corsaro, Molinari, & Rosier, 2002). Perhaps the unique socialization experiences of children from lower-income families, specifically their development of an interdependent self-concept and their more socially oriented language use, foster social-cognitive strengths.

Strength in social cognition can be harnessed in educational practices to facilitate learning. Lucariello, Butler, and Tine (2012) developed a socially based curriculum to teach reading comprehension strategies to low-income children at an urban school. Reading was converted to a social domain through multiple mechanisms, including the personification of strategies and the creation of innovative concept definitions that recruit social cognition. Compared to 3rd graders randomly assigned to a more traditional curriculum, students in the socially based curricular group did better on tasks that required application of making inferences and visualizing (Lucariello et al., 2012). Palincsar and Magnusson's (2001) production and use of a "scientist's notebook" instead of a textbook is another successful case of employing students' social-cognitive skills to benefit learning. As these findings suggest that children's social-cognitive strengths may be recruited to improve academic performance in reading and science, the current study investigates whether such strengths can be observed in mathematics problem-solving.

There have been efforts to make mathematics more socially based to maximize learning. Specifically, a narrative approach has been utilized whereby math problems are contexted in a story (Lubinski & Thiessen, 1996). Another social modification of math curricula has entailed linking children's own life experiences with mathematical learning in the classroom (Lo Cicero, De La Cruz, & Fuson, 1999). Reliance on activities that are collective, are goal-directed, and entail artifacts is an approach that utilizes the social/interpersonal domain in math education (Saxe, 2002; Saxe & Guberman, 1998). Children engage in a wide variety of everyday activities that entail mathematics, such as buying and selling (candy, lemonade), singing counting songs, comparing, measuring, and keeping score in games and sports. The suggestion here is that mathematics that is embedded within a socially based problem-solving context may capitalize on lower-income children's strength in social reasoning.

Context is used to mean "the words…that help the students to understand the task…or the event in which the task is situated" (Van den Heuvel-Panhuizen, 2005, p. 2). Context here does not refer to the physical/social learning environment. Abstract formats for mathematical problem-solving are usually defined as bare number problems (Van den Heuvel-Panhuizen, 2005) or symbolic equations that contain no words; however, other abstract representations have been used that included words, but the language is impersonal, and all mathematical quantities remain abstract, without any object referents.

Previous research regarding whether students generally perform better on contextualized word problems versus abstract problems yields mixed findings. The benefits of contextualization have been shown at the level of elementary arithmetic (Carraher, Carraher, & Schliemann, 1985, 1987; Baranes, Perry, & Stigler, 1989) as well as with higher-level arithmetic problems involving fractions and decimals (Jarvin, McNeil, & Sternberg, 2006; Rittle-Johnson & Koedinger, 2005). There has also been evidence that contextualized story problems are easier to solve than symbolic problems in the domain of early algebra (Koedinger & Nathan, 2004). Yet other scholars have shown that students are more successful solving symbolic equations than contextualized problems (Boaler, 2003; Lubienski, 2000; Pike & Forrester, 1997). Theoretical frameworks suggest that word problems require greater working memory capacity than symbolic equations (Kintsch & Greeno, 1985). Also, researchers explain that because word problems involve linguistic information, students need to seek and find underlying structural information and construct a problem model in order to solve the problem correctly (Fuchs et al., 2008; Xin, 2007).

Cooper and Dunne's work (1998, 2000) describes how items used in England's National Curriculum assessment in mathematics that embed mathematical operations in realistic contexts are interpreted differently by children from different social classes. They suggest that the trend to assess mathematics understanding with realistic items actually furthers the income-based performance divide. Children from working class families are often not able to demonstrate their mathematical competencies due to the constraints of the test and how it is scored (Boaler, 2003; Cooper & Dunne, 1998, 2000).

Literature on realistic problems and the effects of context on students' processing of mathematics word problems reveals many unresolved issues and highlights a need for further investigation into the role of sociocultural factors in children's reasoning. As Van den Heuvel-Panhuizen (2005) recommends, more "research into the effects of alterations in presentations and comparing context problems with bare problems" is needed (p. 9). The current study investigates whether situational contexts for mathematics word problems, specifically those that are *socially* based, lead to more accurate performance than two different abstract formats (symbolic equations and decontextualized word problems) for children from lower- and higher-income families.

An additional goal of this study was to examine whether children will not only perform better, but also feel more confident in their mathematics abilities when the mathematics is embedded in socially salient and relevant word problems. According to Bandura's (1986) social cognitive theory, people's judgments of their own capabilities to accomplish specific tasks strongly influence human motivation and behavior. *Perceived self-efficacy* refers to "beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments" (Bandura, 1997, p. 3). The current study considers children's *mathematics self-efficacy*—"individuals' judgments of their capabilities to solve specific math problems"—and whether it varies for different problem types (Pajares & Miller, 1994, p. 194). There has been ongoing interest in the precise nature of the relationship between self-efficacy and academic achievement, as "high self-efficacy is likely to promote stronger academic performances" (Pajares, 1996, p. 325). Pajares (1996) explains,

> Mathematics has received special attention in self-efficacy research given its foundational status in the academic curriculum and the acknowledged importance of mathematics self-efficacy beliefs in students' selection of math-related activities and pursuit of math-related majors and careers. (p. 326)

We know that "self-efficacy beliefs act as determinants of behavior by influencing the choices that individuals make, the effort they expend, the perseverance they exert in the face of difficulties, and the thought patterns and emotional reactions they experience" (Pajares, 1996, p. 325). Thus, if lower-income children possess greater personal efficacy beliefs related to mathematics that is embedded in socially based problem-solving tasks, there are implications for curriculum. Perhaps mathematics curriculum that recruits lower-income children's cognitive capital (in the form of social reasoning) by embedding mathematics in a social problem-solving context could improve the mathematics self-efficacy of these students and be linked to better academic performance.

The Present Study

While the income-based achievement gap in mathematics is well-documented, the studies above showing that children from lower-income backgrounds do not lag behind in high-level social reasoning tasks laid the foundation for the current research. The purpose of the present study was to investigate whether mathematics problems with a social reasoning component would yield higher mathematics performance and/or mathematics self-efficacy than other problem types for lower- and higher-income students.

For this research, 5th graders were chosen as the population of interest because they allowed for the impact of socially based contextualization to be assessed on more sophisticated arithmetic (i.e., multiplication of 1- and 2-digit whole numbers) as opposed to the more commonly studied arithmetic operations of addition and subtraction or algebra. This study systematically examines the impact of contextualizing math problems for lower-income children as compared to their higher-income peers. This study also extends the line of research that has sought to isolate which aspects of contextualizing math problems are most beneficial and for which particular groups of students (e.g., Jarvin et al., 2006), as it includes an innovative version of contextualization – one which embeds mathematics in an interpersonal/social context and seeks to recruit children's social ToM.

In addition, this work addresses a need to consider motivational factors in relation to low-income children's poor math performance (Arnold & Doctoroff, 2003). An innovative goal of this study was to examine the relation between children's mathematics self-efficacy and their problem-solving capabilities for multiplication problems represented in social and abstract formats.

Ultimately, this study highlights two issues related to the mathematical problem-solving of higher- and lower-income children. One is the effect of various problem formats on problem-solving accuracy and mathematics self-efficacy. The second is the relation among problem format, self-efficacy, and problem-solving. To this aim, specific research questions regarding (1) the impact of symbolic equations versus word problems on children's accuracy and self-efficacy, (2) the impact of socially modified word problems on children's accuracy and self-efficacy, and (3) the relation between children's mathematics performance and mathematics self-efficacy were explored.

Method

Participants

Participants were 164 5th graders drawn from 10 classrooms within five public schools. There were 66 children in the lower-income group and 98 in the higher-income group. Lower-income children were defined as those qualifying for free/reduced-price lunch through the National School Lunch Program as reported by school personnel. The full sample included 89 males and 75 females (lower-income: 35 girls, 31 boys; higher-income: 54 girls, 44 boys). The mean age of the full sample was 10.9 years, range 10.0–12.2 years (lower-income: 11.1 years; higher-income: 10.9 years).

Ethnic/racial identification was self-reported by the participants on a student information sheet. The ethnic-racial distribution of lower-income children was: White 23%, Black 23%, Hispanic 24%, Asian 12%, Native American 1%, Other 17%. The distribution of the higher-income children was: White

81%, Black 2%, Hispanic 2%, Asian 8%, Native American 1%, Other 6%. Ultimately, four participants were excluded from the analyses because their test packets were missing pages.

Measures

Standardized Test Scores

Participants' 4th grade state standardized test scores for mathematics and English/language arts were obtained for those students whose parents consented to release the scores (85% of lower-income; 87% of higher-income). These data served as indices of participants' baseline mathematical and reading abilities. Standardized test scores range from 200 to 280 and cover four performance levels: *Advanced* (260–280); *Proficient* (240–259); *Needs Improvement* (220–239); and *Failing* (200–219). The higher-income group performed significantly better on the standardized mathematics test (M = 254.75, SD = 16.56; range 216–280) than the lower-income group (M = 234.86, SD = 15.52; range 216–268), t = -7.16, p < .001. The higher-income group (M = 249.00, SD = 13.81; range 216–280) also outperformed the lower-income group (M = 235.75, SD = 15.17; 210–266) on the English/language Arts test, t = -5.36, p < .001.

Mathematics Problem-Solving Test

The mathematics problem-solving test contained 16 multiplication (of one- and two-digit whole numbers) problems, representing four different problem formats (two social, two abstract). There were four problems per each of the four format types. Of the four problem formats, three (two social, one abstract) entailed word problems and one (abstract) was a symbolic presentation. When constructing the situational context for the word problems, many features were controlled for across problem format type, such as vocabulary, grammatical complexity, and word count.

Socially Based Problems

Two types of socially based problems were presented. The first type was *everyday activity problems*. These problems depicted the type of everyday problem-solving that is relied upon by a situated cognition/collective practices theoretical perspective (Kirschner & Whitson, 1997). The situational context of these problems was an everyday cultural practice that involved mathematics. Buying and selling typical products at school was the specific activity. Coin referents (nickel or quarter) were used for one of the factors in order to elicit students' practical knowledge. To further encourage the participants to imagine themselves actually engaged in the buying and selling described in the problems, second person ("you") was used as the agent.

The second type of socially based problems was *social-cognitive problems*. These word problems included social contexts that entailed interpersonal goals based on an agent's desires and beliefs. These problems were intended to recruit social-cognitive abilities such as social ToM (i.e., reasoning about others' mental states). Thus, a unique feature of these problems was that they all included two mental state verbs: "wants" and "thinks." The interpersonal/social context of social-cognitive problems aimed to engage the learner socio-emotionally by involving a relatable, high-stakes issue that would be relevant to 5th graders. Since many of the cognitive tasks that are used to assess ToM abilities rely on children's understanding of deception, all of the social-cognitive problems involved some element of deception (e.g., winning over the teacher, bribing friends with presents) to achieve an end. In these problems, an "other" person was used as the agent instead of "you" so that the participants' social reasoning skills (i.e., social ToM) were recruited.

Abstract Problems

Two types of abstract problems were included on the mathematics problem-solving test. The first type was *traditional textbook* problems. These problems focused on inanimate objects such as sticks and rocks. Unlike the two socially based word problems, the traditional textbook problems did not include an agent. Impersonal language ("There were…") was used instead. The traditional textbook problems were intended to represent the typical word problems that appear in many elementary mathematics textbooks. These types of word problems have non-essential context; one thing can be exchanged for another without substantially altering the problem (e.g., adding marbles can be switched to adding pounds of ham) (Van den Heuvel-Panhuizen, 2005).

The second type of abstract problems was *symbolic equations*. For these problems, students were asked to solve mathematical problems that were presented completely in symbolic format. The symbolic problems were displayed horizontally (as equations) in the mathematics test.

Problem Difficulty

For each presentation format (two social and two abstract), students were given two easy problems and two difficult problems. Easy problems were defined as single-step problems that involved multiplication of a two-digit whole number by a one-digit whole number. Difficult problems were defined as single-step problems that involved multiplication of a two-digit whole number by another two-digit whole number.

Tests were counterbalanced to ensure randomization of problem order in terms of presentation format and problem difficulty. A random number generator was used to create one unique problem set order per participant. See Table 1 for examples of easy and difficult versions of the four problem types.

Table 1: *Examples of Problem Types*

	Easy: Single-Step Multiplication of 1- and 2-Digit Whole Numbers	Difficult: Single-Step Multiplication of Two 2-Digit Whole Numbers
	Social	
Everyday activity: Situational context is an everyday cultural practice that involves mathematics (buying and selling typical products at school). Coin referents (nickel, quarter) are used for the multiplier to elicit practical knowledge. Second person ("you") is the agent.	Problem #1 You sell 19 milk chocolate candy bars to raise money for your 5th grade field trip. You charge a nickel for each milk chocolate candy bar that you sell. How many cents do you raise selling milk chocolate candy bars for your 5th grade field trip?	Problem #2 You sell 19 packages of bubble gum to raise money for your 5th grade class trip. You charge a quarter for each package of bubble gum that you sell. How many cents do you raise selling packages of bubble gum for your 5th grade class trip?
Social-cognitive: Interpersonal/social context entails interpersonal goals based on an agent's desires and beliefs and is intended to recruit social theory of mind (reasoning about others' mental states). Two mental state verbs ("wants" and "thinks") are used. Some element of deception (to achieve an end) is involved. Third person ("John") is the agent.	Problem #3 John wants better grades in math. He thinks that if he is the teacher's pet, he will get better grades in math. John spends 15 minutes every day helping the teacher. After 4 days, how many minutes has John spent trying to win over the teacher?	Problem #4 Gina wants better test scores in math. She thinks that if she is the teacher's pet, she will get better test scores. Gina spends 35 minutes every day helping the teacher. After 13 days, how many minutes has Gina spent trying to win over the teacher?
	Abstract	
Traditional textbook: Situational context is non-essential and/or focuses on inanimate objects (e.g., sticks and rocks). These problems represent the typical word problems in mathematics textbooks. No agent; impersonal language is used instead.	Problem #5 There are 15 bundles of long brown sticks gathered together in a very big pile on the ground. Each of these bundles has 7 long brown sticks in it. How many long brown sticks are there altogether in the very big pile of bundles?	Problem #6 There are 16 bundles of short black wires gathered together in a very big pile on the ground. Each of these bundles has 55 short black wires in it. How many short black wires are there altogether in the very big pile of bundles?
Symbolic: No words are used.	Problem #7 $14 \times 7 =$	Problem #8 $16 \times 45 =$

Mathematics Self-Efficacy Measure

Students were asked to complete a mathematics self-efficacy rating form that included eight additional multiplication problems. This measure was structured in the same way as the mathematics problem-solving test, in that the same four problem types and two levels of problem difficulty were included; however, whereas the mathematics problem-solving test included four problems per each of the four format types (two easy, two difficult), the mathematics self-efficacy measure included just two problems per format type. The measures were counterbalanced to ensure randomization of problem order in terms of presentation format and problem difficulty.

Research on mathematics self-efficacy states that “researchers are encouraged to use similar—but not identical—items to assess self-efficacy and performance” (Marsh, Roche, Pajares, & Miller, 1997, p. 374). It is also recommended that the self-efficacy measure be administered “as closely as possible in time” to the math performance task (Pajares, 1996, p. 328). This method is advised because efficacy judgments are considered to be task-specific (Bandura, 1986, 1997; Nielsen & Moore, 2003). Thus, for each of eight math problems on the self-efficacy measure, students were asked to provide a specific math self-efficacy rating. Per Bandura’s (2001) recommendations, the self-efficacy measure consisted of a 10-point scale for each math problem, with the scale ranging in 1-unit intervals from 0 (“I’m very sure I cannot do that”); through intermediate degrees of assurance, 5 (“I’m not sure if I can do that or not”); to complete assurance, 10 (“I’m very sure I can do that”). These ratings from each student and for each type of math problem served as specific measures of mathematics self-efficacy.

Prior to the final construction of the measures, pilot testing was conducted to ensure that the numerical content of the math problems was statistically equivalent within all easy and difficult problems and across problem types.

Procedure

All measures were administered within each 5th grade classroom. First, students completed the mathematics problem-solving test. Next, the experimenter led the children in a practice task to familiarize them with the scale for rating their perceived self-efficacy and to make sure that they could interpret and use it correctly (following Bandura, 2001). Then, each child was administered the mathematics self-efficacy scale. Students were specifically instructed not to attempt to answer the problems while they provide their self-efficacy ratings. In order to ensure that this practice was followed, the experimenter and classroom teacher carefully proctored. Finally, participants recorded demographic data on an information sheet.

Data Scoring

For the problem-solving test, participants’ responses were coded as correct or incorrect based on whether the appropriate final product was calculated for each problem. A mathematics problem-solving test total score (0–16) was calculated and then converted to a proportion (0–1). Subscores were calculated to represent the total number of problems solved correctly within each problem type (0–4) and within the subgroups of easy (0–8) and difficult (0–8) problems. These scores were also converted to proportions.

Participants’ ratings (0–10) for each of the eight problems on the self-efficacy measure were summed to create an overall mathematics self-efficacy total score (0–80). This was divided by the number of problems (eight) to yield an average self-efficacy total score (0–10). Average self-efficacy subscores were also calculated for each of the four problem types and for the subgroups of easy and difficult problems.

Results

Mathematics Problem-Solving Test

To examine participants' performance on the mathematics problem-solving test, a 2 × 4 × 2 repeated measures ANOVA was run with income as the between-subjects factor and problem type (everyday activity, social cognitive, traditional textbook, and symbolic) and level of problem difficulty (easy, difficult) as the two within-subjects factors. Mauchly's test indicated that the assumption of sphericity had been violated for the main effect of problem type (x^2 [5] = 15.77, $p < .01$) and for the problem type X difficulty interaction (x^2 [5] = 28.41, $p < .01$); therefore, degrees of freedom were corrected using Huynh-Feldt estimates of sphericity ($\varepsilon = .97$ for problem type and $\varepsilon = .91$ for the interaction). To better understand the significant effect of problem type and to adjust for multiple comparisons, least significant difference post-hoc analyses were conducted.

Results indicate a significant main effect of income, with higher performance by the higher-income group ($M = .92$, $SD = .17$) than the lower-income group ($M = .76$, $SD = .17$), $F(1, 158) = 35.57$, $p < .001$. There was also a significant main effect of problem type, $F(2.90, 457.68) = 10.14$, $p < .001$. Across income and problem difficulty, participants performed best on the symbolic problems. A significant main effect of problem difficulty was also reported, with participants demonstrating greater accuracy on easy versus difficult problems, $F(1, 158) = 59.71$, $p < .001$. See Table 2.

Table 2: *Means (Proportion Correct) and Standard Deviations by Problem Type and Difficulty for the Math Problem-Solving Test*

Variable	Lower Income n = 65 *M*	*(SD)*	Higher Income n = 95 *M*	*(SD)*	Full Sample n = 160 *M*	*(SD)*
Problem Type						
Everyday activity total	.73	(.23)	.88	(.22)	.81	(.23)
Easy	.82	(.29)	.91	(.23)	.86	(.27)
Difficult	.64	(.39)	.86	(.26)	.75	(.33)
Social-cognitive total	.76	(.22)	.92	(.21)	.84	(.23)
Easy	.89	(.26)	.96	(.14)	.93	(.20)
Difficult	.63	(.42)	.88	(.25)	.76	(.33)
Traditional textbook total	.70	(.24)	.93	(.24)	.81	(.25)
Easy	.77	(.35)	.94	(.18)	.86	(.27)
Difficult	.63	(.43)	.91	(.23)	.77	(.33)
Symbolic total	.84	(.19)	.95	(.19)	.90	(.19)
Easy	.93	(.21)	.96	(.16)	.94	(.19)
Difficult	.75	(.38)	.95	(.17)	.85	(.28)
Problem Difficulty						
Easy	.85	(.15)	.94	(.16)	.90	(.15)
Difficult	.66	(.23)	.90	(.22)	.78	(.23)

There were also significant interaction effects between income and problem type, $F(2.90, 158) = 3.14$, $p < .05$, and between income and problem difficulty, $F(1, 158) = 24.06$, $p < .001$. One of the most compelling findings was that the lower-income group performed better on the social-cognitive problems than on the traditional textbook problems ($p < .05$), which was not the case for the higher-income group, where they were equivalent. See Figure 1.

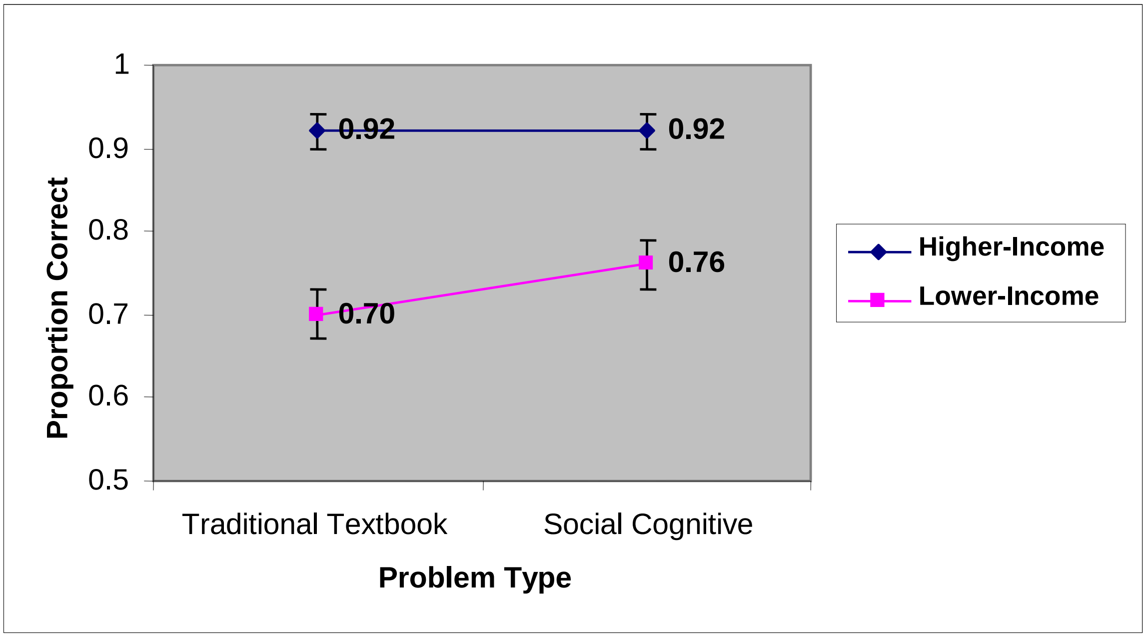

Figure 1: *Proportion Correct on Traditional Textbook and Social Cognitive Problem Types by Lower- and Higher-Income Groups*

Additionally, level of problem difficulty had a bigger impact on the performance of lower-income students compared to higher-income students ($p < .001$). See Figure 2.

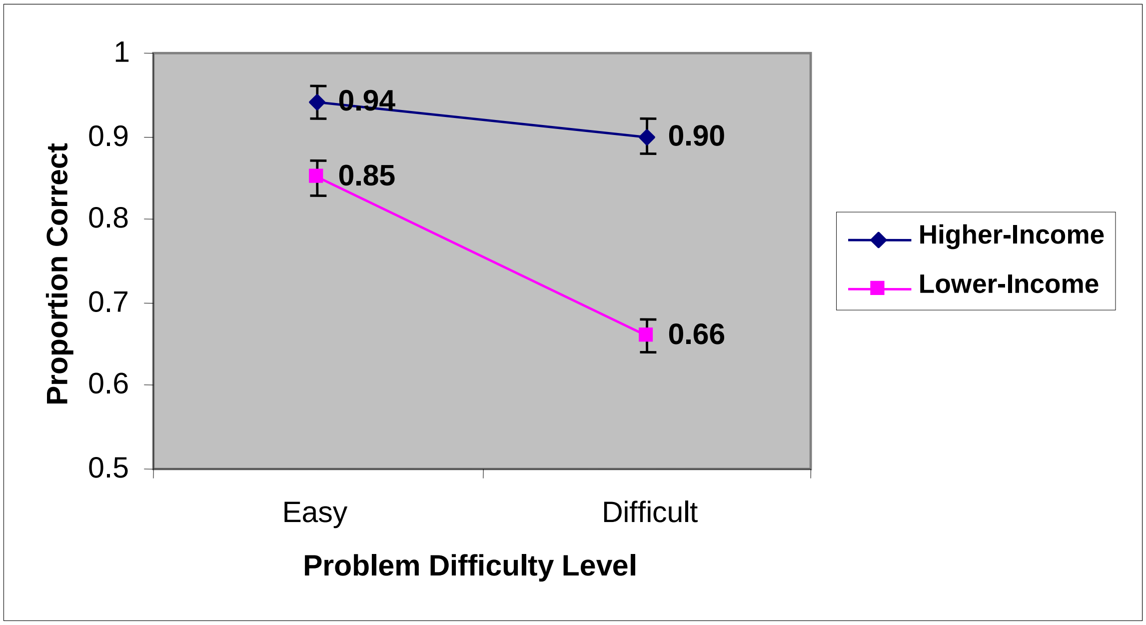

Figure 2: *Proportion Correct on Easy and Difficult Problems by Lower- and Higher-Income Groups*

Mathematics Self-Efficacy Measure

To examine children's ratings of mathematics self-efficacy, another 2 × 4 × 2 repeated measures ANOVA was run with income as the between-subjects factor and problem type (everyday activity, social cognitive, traditional textbook, and symbolic) and level of problem difficulty (easy, difficult) as the two within-subjects factors. Mauchly's test indicated that the assumption of sphericity had been met for each of the effects in the model. Least significant difference post-hoc analyses were conducted to adjust for multiple comparisons.

Results show a significant main effect of income, with the higher-income group (M = 9.61, SD = .79) providing significantly higher self-efficacy ratings than the lower-income group (M = 9.01, SD = .79), $F(1, 158) = 22.12$, $p < .001$. There was also a significant main effect of problem type, $F(3, 474) = 6.58$, $p < .001$. Participants provided significantly higher self-efficacy ratings for the symbolic problems than for either of the two social problem types ($p < .01$); however, there were no differences between participants' self-efficacy ratings for the symbolic problems and for the traditional textbook problems. A significant main effect of problem difficulty was also reported, $F(1, 158) = 30.22$, $p < .001$, with higher self-efficacy ratings for the easy problems than for the difficult problems. See Table 3.

Table 3: *Mean Self-Efficacy Ratings and Standard Deviations by Problem Type and Difficulty for the Problems on the Math Self-Efficacy Measure*

	Lower Income $n = 65$		Higher Income $n = 95$		Full Sample $n = 160$	
Variable	*M*	*(SD)*	*M*	*(SD)*	*M*	*(SD)*
Problem Type						
Everyday activity total	8.89	(1.14)	9.58	(1.14)	9.24	(1.15)
Easy	9.15	(1.37)	9.64	(.80)	9.40	(1.09)
Difficult	8.63	(1.88)	9.53	(1.04)	9.08	(1.47)
Social-cognitive total	8.69	(1.28)	9.55	(1.28)	9.12	(1.30)
Easy	8.85	(1.84)	9.63	(.98)	9.24	(1.42)
Difficult	8.52	(1.92)	9.46	(1.02)	8.99	(1.48)
Traditional textbook total	9.12	(.91)	9.67	(.92)	9.39	(.94)
Easy	9.32	(1.36)	9.76	(.68)	9.54	(1.02)
Difficult	8.91	(1.45)	9.58	(.78)	9.24	(1.13)
Symbolic total	9.36	(.90)	9.65	(.91)	9.51	(.92)
Easy	9.58	(.97)	9.76	(.63)	9.67	(.80)
Difficult	9.14	(1.58)	9.54	(.87)	9.34	(1.23)
Problem Difficulty						
Easy	9.23	(.73)	9.70	(.74)	9.46	(.75)
Difficult	8.80	(.97)	9.52	(.96)	9.16	(.99)

The ANOVA run on the mathematics self-efficacy measure showed significant interaction effects between income and problem type, $F(3, 158) = 3.26$, $p < .05$, and between income and problem difficulty, $F(1, 158) = 5.70$, $p < .05$. While the higher-income group showed no significant differences in self-efficacy ratings for the four problem types, the lower-income group provided higher self-efficacy ratings for the traditional textbook problems than for the social-cognitive problems ($p < .01$). See Figure 3.

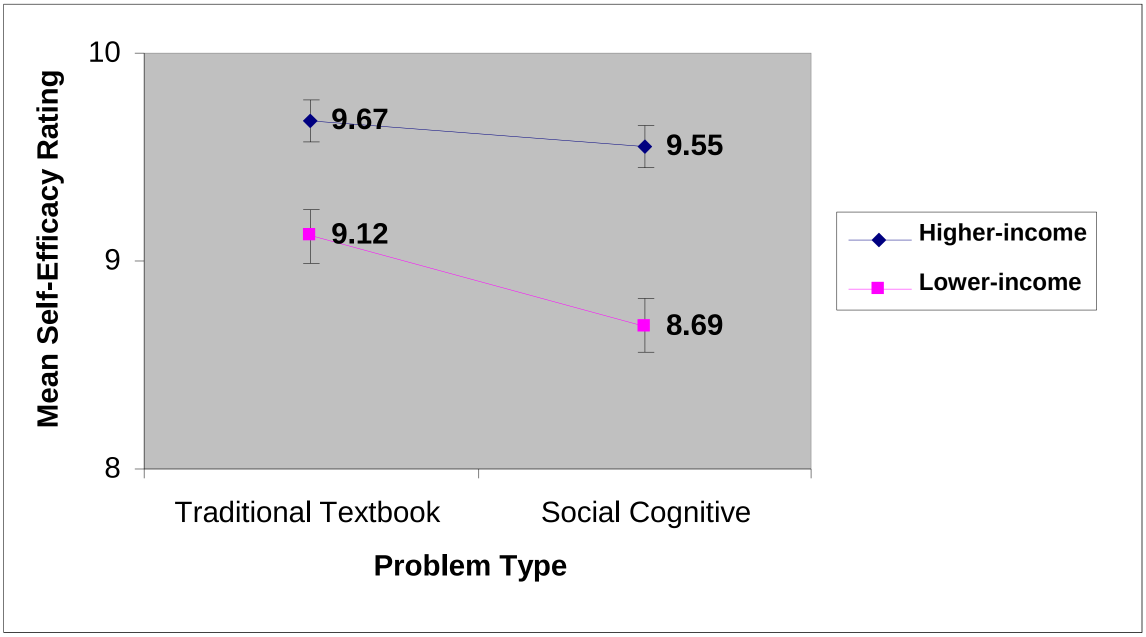

Figure 3: *Mean Self-Efficacy Ratings for Traditional Textbook and Social Cognitive Problem Types by Lower- and Higher-Income Groups*

Additionally, level of problem difficulty had a bigger impact on the self-efficacy ratings of lower-income students compared to higher-income students, ($p < .001$). See Figure 4.

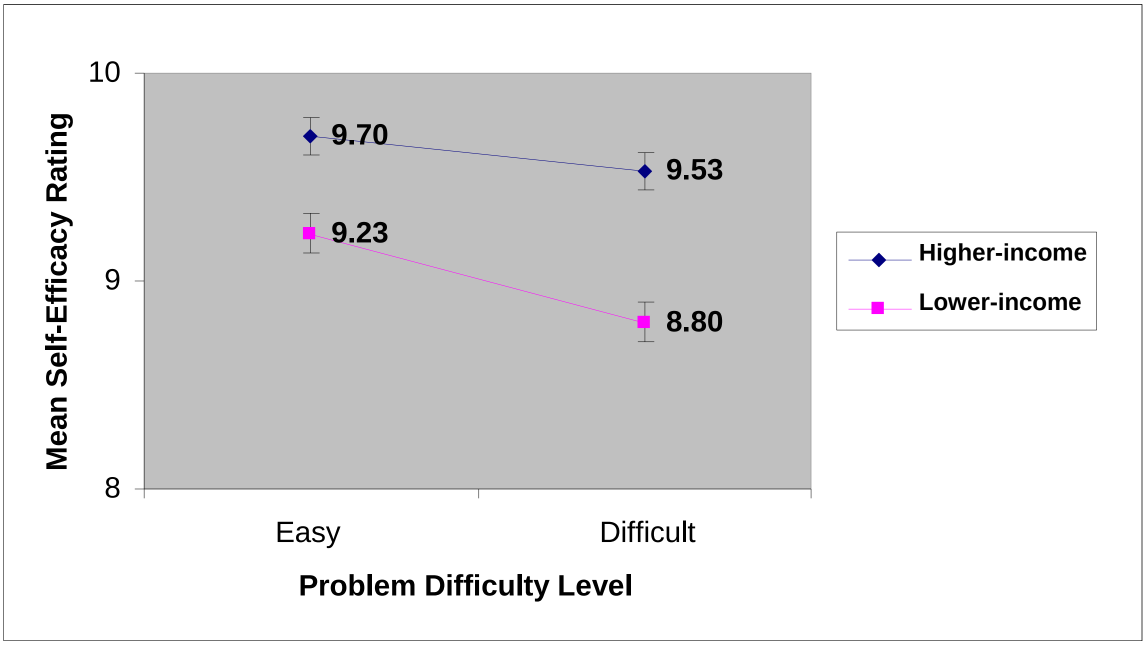

Figure 4: *Mean Self-Efficacy Ratings for Easy and Difficult Problems by Lower and Higher-Income Groups*

Relation Between Mathematics Problem-Solving and Mathematics Self-Efficacy

To explore the unique contribution of students' mathematics self-efficacy ratings to their performance on the mathematics problem-solving test, a series of stepwise linear regression analyses were conducted. Math self-efficacy total score accounted for 8% of the variance in total math problem-solving score over and above the factors of income, gender, and standardized math and English/language arts test scores $F(1, 127) = 17.58$, $p < .001$. See Table 4.

Table 4: *Stepwise Regression of Total Math Problem-Solving Score on Income, Gender, Standardized Test Scores, and Total Math Self-Efficacy Score*

Variable	ΔR^2	*B(SE)*	β	R^2
Step 1				
Income[a]	.22***	.18(.03)	.47***	.22
Step 2				
Gender[b]	.00	-.02(.03)	-.06	.22
Step 3				
Standardized math	.14***	.01(.00)	.44***	.36
Step 4				
Standardized English	.03*	.00(.00)	.30*	.39
Step 5				
Total math self-efficacy	.08***	.07(.02)	.31***	.46

Note: Betas are for final step in the model; *$p < .05$, **$p < .01$, ***$p < .001$;
[a]lower-income = 0; higher-income = 1; [b]male = 0; female = 1

Next, separate stepwise linear regressions were run for each of the four problem types and for easy and difficult problems. In all cases except for the traditional textbook problems, math self-efficacy predicted problem-solving performance. See Tables 5 and 6.

Table 5: *Stepwise Regressions of Math Problem-Solving Score on Income, Gender, Standardized Test Scores, and Math Self-Efficacy Score for Each Problem Type*

Variable	ΔR^2	*B(SE)*	β	R^2
Step 1				
Income[a]	.14***	.18(.04)	.37***	.14
Step 2				
Gender[b]	.01	.04(.04)	.09	.15
Step 3				
Standardized math	.04**	.00(.00)	.25**	.19
Step 4				
Standardized English	.01	.00(.00)	.20	.20
Step 5				
Everyday activity self-efficacy	.07***	.06(.02)	.30***	.28
Step 1				
Income[a]	.09***	.15(.04)	.30***	.09
Step 2				
Gender[b]	.01	-.06(.04)	-.11	.10
Step 3				
Standardized math	.19***	.01(.00)	.50***	.29
Step 4				
Standardized English	.01	.00(.00)	.22	.30
Step 5				
Social-cognitive self-efficacy	.11***	.07(.02)	.37***	.41
Step 1				
Income[a]	.17***	.23(.05)	.41***	.17
Step 2				
Gender[b]	.00	-.00(.05)	-.01	.17
Step 3				
Standardized math	.12***	.01(.00)	.40***	.28
Step 4				
Standardized English	.05**	.01(.00)	.42**	.33
Step 5				
Textbook self-efficacy	.01	.02(.02)	.08	.34
Step 1				
Income[a]	.07**	.11(.04)	.26**	.07
Step 2				
Gender[b]	.00	-.02(.04)	-.04	.07
Step 3				
Standardized math	.11***	.00(.00)	.39***	.18
Step 4				
Standardized English	.01	.00(.00)	.22	.19
Step 5				
Symbolic self-efficacy	.06**	.05(.02)	.25**	.25

Note: Betas are for final step in the model; $^*p < .05$, $^{**}p < .01$, $^{***}p < .001$; [a]lower-income = 0; higher-income = 1; [b]male = 0; female = 1

Table 6: *Stepwise Regressions of Math Problem-Solving Score on Income, Gender, Standardized Test Scores, and Math Self-Efficacy Score for Easy and Difficult Problems*

Variable	ΔR^2	*B(SE)*	β	R^2
Step 1				
Income[a]	.11***	.11(.03)	.33***	.11
Step 2				
Gender[b]	.00	-.01(.03)	-.03	.11
Step 3				
Standardized math	.07**	.00(.00)	.32**	.18
Step 4				
Standardized English	.03*	.00(.00)	.32*	.21
Step 5				
Self-efficacy for easy problems	.07**	.06(.02)	.30**	.28
Step 1				
Income[a]	.21***	.24(.04)	.45***	.21
Step 2				
Gender[b]	.00	-.01(.04)	-.02	.21
Step 3				
Standardized math	.18***	.01(.00)	.50***	.38
Step 4				
Standardized English	.02*	.00(.00)	.27*	.41
Step 5				
Self-efficacy for difficult problems	.04**	.06(.02)	.23**	.45

Note: Betas are for final step in the model; *$p < .05$, **$p < .01$, ***$p < .001$;
[a]lower-income = 0; higher-income = 1; [b]male = 0; female = 1

Discussion

This study addressed: (1) the relative difficulty of symbolic equations versus word problems, (2) the impact of socially modifying word problems on children's accuracy and self-efficacy, and (3) the relation between children's mathematics performance and mathematics self-efficacy.

Mathematics Problem-Solving Performance

One key finding on problem format was that children performed better on symbolic multiplication problems than on word problems. Indeed, both the lower- and higher-income groups performed better on the symbolic equations than on any of the three word problem types. This finding is consistent with the body of research that reports symbolic formats are easier for elementary school-aged children to solve than matched word problems (Abedi & Lord, 2001; Fuchs et al., 2008; Xin, 2007). Moreover, this study provides particularly strong evidence that symbolic problems are easier than word problems for elementary school children since three types of word problems (two socially contextualized and one abstract) and two levels of difficulty were systematically tested. In all cases, and for both income groups, the strongest performance was observed for the symbolic problems.

One significant reason that symbolic problems may be easier to solve than word problems pertains to the explicitness of the operation. In word problems, the operations are not explicitly stated, and therefore, the student must determine which operation to perform as well as which pieces of information in the problem to use. In the present study, only multiplication problems were involved. This provides even stronger evidence that symbolic problems are easier for students, since the word problems used in this study were inherently less difficult due to the fact that multiplication was always entailed. Even with the operation being quite obvious for the word problems, the participants still performed better on the symbolic equations. In this study, the requirement of greater working memory capacity and linguistic ability for solving word problems than for solving symbolic equations may explain why participants demonstrated poorer performance on the word problems (Abedi & Lord, 2001; Kintsch & Greeno, 1985).

Given that mathematical word problems have been found to be challenging for students, this research sought to address whether certain word problem presentation formats would facilitate greater problem-solving performance for students and whether there would be income-related differences. Word problem variation did have a significant effect on mathematical problem-solving for the lower-income children, who demonstrated greater accuracy on the social-cognitive problems than on the traditional textbook problems. This finding may support the view that lower-income children possess social-cognitive capital (Lucariello et al. 2007; Lucariello et al., 2012) that can be successfully harnessed in mathematics problem-solving.

This research has offered a new conceptualization of a contextualized word problem– one that may build upon on the social reasoning strengths of children from lower-income families by engaging their strength in reasoning about others (e.g., perspective taking, considering an agent's desires and beliefs, understanding the use of deception to attain interpersonal goals) in the comprehension and/or solution of the problem. Certainly additional research is needed to better understand if and how social reasoning strengths may be used during the problem-solving process, but this finding suggests that future exploration is warranted.

This study sought to explore specifically whether everyday activity problems would prove to be an effective mode of contextualization for both lower- and higher-income children. Interestingly, results showed that it was no more effective than a decontextualized word problem for either income group. This finding is noteworthy because it challenges current trends in education, such as the emphasis on everyday mathematics and real-world problem-solving.

In contrast to the findings for the lower-income children, word problem variations did not have an effect for the higher-income children. They performed comparably across all three word problem types; however, it should be noted that the higher-income participants scored very well on the word problems, averaging between 88% and 92% correct across the three verbal formats. It might be the case that word problem format would have an effect for higher-income children prior to their attaining mastery in a particular mathematical operation or for mathematics operations other than multiplication.

Not surprisingly, findings indicated that all students performed better on the easy problems than on the difficult problems for all problem format types. Further, problem difficulty had a greater impact on the performance of lower-income students than higher-income students.

Mathematics Self-Efficacy Ratings by Income, Problem Format, and Difficulty

Results showed that, overall, children's mathematics self-efficacy ratings for the multiplication problems were very high, which is consistent with previous findings that children's self-reported ratings of self-efficacy tend to be inflated (e.g., Pajares, 1996; Pajares & Kranzler, 1995); however, differences by income group were still observed. There was a main effect of income, with higher-income children consistently providing higher self-efficacy ratings than the lower-income children.

Across income groups, participants gave higher self-efficacy ratings to the symbolic problems than to either of the two social word problems; however, the traditional textbook problems received self-efficacy ratings that were equally as high as the symbolic problems. Children were more certain that they would be able to solve either the symbolic or traditional textbook word problems correctly than they would be able to solve either of the two socially based word problems. One explanation may be that the socially based word problems, especially the social-cognitive problems, are unfamiliar. Indeed, most would agree that the majority of children's mathematics instruction and practice entails symbolic equations (Nathan, Long, & Alibali, 2002).

While higher-income children provided equivalent self-efficacy ratings for all three word problems (and the symbolic format), the lower-income group actually felt more certain that they would be able to solve the traditional textbook problems correctly than the social-cognitive problems. The reverse pattern was observed for the lower-income group on the mathematics problem-solving test. Indeed, the lower-income children showed stronger math performance on the social-cognitive problems than on the traditional textbook problems, but they subsequently rated social-cognitive problems lower than traditional textbook problems in terms of self-efficacy. Again the greater familiarity with "traditional textbook" style word problems may account for the higher self-efficacy ratings for those problems. This is consistent with Lubienski's (2000) finding that lower-income students express a preference a more traditional approach to problem-solving.

Across income groups, children demonstrated higher self-efficacy for easy problems than for difficult problems. A similar pattern emerged as for the mathematics problem-solving test whereby difficult problems more substantially influenced lower-income children's self-efficacy scores than those of higher-income children.

Relation Between Mathematics Performance and Self-Efficacy

Mathematics self-efficacy was shown to predict mathematics performance in this study as in previous work (Pajares & Graham, 1999; Pajares & Kranzler, 1995). Indeed, students' total mathematics self-efficacy scores uniquely predicted their total mathematics problem-solving scores. Moreover, math self-efficacy scores for each problem type contributed uniquely to the variance in problem-solving scores for all types *except* the traditional textbook problems. The fact that the link between self-efficacy and performance did not hold for the traditional textbook problems reflects the finding that lower-income children provided high self-efficacy ratings for the traditional textbook problems (perhaps because they seemed familiar), although, they performed worse on the textbook problems than on those that were socially based. Finally, the analyses showing that mathematics self-efficacy scores for easy and difficult problems predicted mathematics problem-solving performance on easy and difficult problems lends further support to the association between self-efficacy and achievement.

Limitations

A limitation of the study derives from the finding that across income groups, participants scored fairly high on all items on the mathematics problem-solving test. This was surprising since pilot testing had not suggested that the items were too easy. Perhaps administering the measures to children in 4th grade, who would be at an earlier stage of mastery, would have yielded greater variance in the scores and revealed even stronger effects of problem format type. Further, it is possible that when faced with more challenging problems, higher-income children would have been more sensitive to the impact of varying problem formats.

Conclusions

There are at least two important implications this research. First, this study provided additional evidence that there exists an achievement gap in mathematics performance between lower- and higher-income children (NCES, 2011; Starkey, Klein, & Wakeley, 2004). Indeed, children's mathematics (and reading) standardized test scores and their math problem-solving test scores were significantly stronger for the higher-income than for the lower-income group.

This study also lends support to the notion that children's social-cognitive strengths may be harnessed to facilitate learning in mathematics problem-solving. A new version of a contextualized word problem—one that includes interpersonal/social contexts that may recruit learners' social ToM abilities—was shown to facilitate mathematics performance for the lower-income group more than other types of word problems. The social-cognitive word problem format is an important contribution of this research and fits Lubienksi's (2002) call to identify particular educational practices that could be promising for lower-income students. Indeed, just as previous research showed achievement gains for lower-income students who were taught reading comprehension with a social-cognitive literacy curriculum (Lucariello et al., 2012), this study shows higher math performance for lower-income students on social-cognitive word problems compared to other types.

While the focus of this research was on systematically testing the context of mathematics word problems, it must be noted that problem format is only one aspect of a highly complex instructional system, where interactions among teachers, students, and content all play a role in learning (Boaler, 2002; Cohen, Raudenbush, & Ball, 2003). Indeed Boaler (2002) has cautioned that educational research has too often focused on what types of curricula should be used in mathematics classrooms, which has "drawn attention away from the teaching practices that mediate student success and that require considerable understanding and support" (p. 244). Indeed, altering problem format on a mathematics assessment has the potential to impact performance but only serves as one factor in the larger teaching and learning system.

Yet, this research suggests that continued systematic examination of mathematical tasks is warranted. Lubienski (2000) wisely notes that changing mathematics curricula and pedagogy has the potential to either remove or add barriers for lower-income students. We know from Cooper and Dunne (1998, 2000) and others that presenting mathematics in a realistic context can be one of these barriers. We also know that understanding the role of context in mathematics problems entails deep examination of the vast manifestations of context that are discussed in the mathematics problem-solving literature (Van den Heuvel-Panhuizen, 2005), and the social-cognitive word problem represents a new iteration of context.

The current findings suggest exciting implications for practice in schools with predominantly low-income populations. The take home message is not that lower-income children should only engage in math problem-solving with social-cognitive word problems, but rather that strength in social cognition, perhaps developed from the unique socialization experiences of lower-income children, is a high-level cognitive skill that can be utilized in academic tasks, such as mathematics problem-solving. Finding creative ways to capitalize on social-cognitive strengths in the classroom may prove to be valuable for improving the academic achievement of lower-income children who continue to lag behind their more socioeconomically advantaged peers.

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