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Empirical

A comparison of predictors of early emerging gender differences in mathematics competency ☆

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Abstract

Five variables (strategy use, fluency, accuracy, spatial ability and confidence) that have been linked to gender differences in mathematics were compared as predictors of mathematics competency. Two hundred and forty-one second grade students from seven schools in Northeast Georgia participated in the study. In fall of the second grade, children were assessed on computation strategies, spatial ability, confidence in mathematics, and accuracy and fluency. In spring, the children took a mathematics competency test. Regression analyses indicated that fluency, accuracy and cognitive strategy use predicted mathematics competency scores. Gender differences were most evident in fluency and the types of strategies used suggesting that it is these variables that influence the emergence of gender differences in math competency. In examining the highest performing group, gender differences in manipulative strategy use were more pronounced in comparison to the total sample, but cognitive strategies were linked to test performance.

Keywords: Gender differences; Mathematics; Strategies; Fluency

1. A comparison of predictors of early emerging gender differences in mathematics achievement

Stable gender differences in mathematics achievement are most evident among gifted populations (e.g., Benbow, 1988) and older students (Hyde, Fennema, & Lamon, 1990). Gender differences are most evident in the upper range of achievement and aptitude test scores with girls being less likely to score at the highest levels. For example, there is a five to one ratio of boys to girls scoring above 600 on the SAT-math test (Stanley & Benbow, 1982). In part, these gender differences are explained by the higher variability of boys' mathematics scores with boys being more likely to be among the best of the best as well as the worst of the worst (Willingham & Cole, 1997) and which are related to mean differences in intellectual abilities (Feingold, 1992). The dearth of girls scoring in the upper range of mathematics achievement tests is of concern because girls may be unable to enter academic programs that require a strong mathematical background (Hedges & Nowell, 1995). There is a need for women to enter careers that require a strong mathematical background as a result of shifting demographics and an expected significant increase in the demand for scientists and engineers (National Science Board, 2000).

A number of theories have been proposed to explain girls' under-representation in the upper range of mathematics test scores and tendency not to choose mathematics related careers. Gender differences in spatial abilities have been hypothesized to underlie gender differences in mathematics achievement with boys being more proficient at three-dimensional mental rotation and having higher mathematics achievement test scores (e.g., Casey, Nuttall, & Pezaris, 1999; Geary, 1996). Social and motivational influences are thought to lessen girls' willingness

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to participate in mathematics (Eccles, 1994). In addition, gender differences in speed of processing and the use of faster, more efficient strategies are thought to give boys an advantage on timed achievement tests (Carr & Davis, 2002; Royer, Tronsky, Chan, Jackson, & Marchant, 1999). There is some evidence supporting each theory, but no single theory can explain all of the data. One reason for this may be that these factors are not independent of each other in their impact on mathematics achievement. One purpose of the current study was to examine how these factors may or may not work together to predict mathematics achievement.

The bulk of the research on gender differences in mathematics has focused on middle and high school populations. This is not surprising given that gender differences in quantitative abilities are most evident in these age groups with little evidence of significant gender differences in elementary school (Halpern, 2000). There is growing evidence, however, that gender differences in mathematics abilities have precursors that emerge during elementary school. Gender differences in many of the factors thought to influence gender differences in mathematics have been found in elementary school including two- and three-dimensional spatial ability (e.g., Levine, Huttenlocher, Taylor, & Langrock, 1999; Linn & Petersen, 1985), speed of processing (e.g., Royer et al., 1999) and strategy use (e.g., Fennema, Carpenter, Jacobs, Franke, & Levi, 1998). Among gifted populations, there is evidence that gender differences in mathematics achievement are already in place by the time children enter elementary school (Robinson, Abbott, Berninger, & Busse, 1996). Recently, Aunola, Leskinen, Lerkkanen, and Nurmi (2004) examined the developmental dynamics of mathematics performance from preschool to second grade. They found no gender differences in mathematics performance but did find that the rate of growth was faster for boys than girls, particularly high performing boys. This finding suggests that gender differences begin in elementary school in the form of different developmental trajectories for boys and girls. A focus of the current study was on the early emerging gender differences in variables hypothesized to be precursors to later developing gender differences in mathematics.

1.1. Strategy use and achievement

As children's knowledge on mathematics develops, the types of strategies they use evolve from strategies that utilize manipulatives to represent number, to internalized cognitive representations of number, and to retrieve answers from memory (Carpenter & Moser, 1984; Fuson, 1992). As children acquire more strategies they have been found to develop a mix of increasingly advanced strategies that they use to solve problems (Kerkman & Siegler, 1993). These more advanced strategies are linked to the emergence of procepts which comprise both the procedures of a strategy and the conceptual knowledge linked to number and strategy (Gray & Tall, 1994). Achievement level is also related to the mix of strategies children possess with gifted children relying more on retrieval whereas less able students rely more on counting strategies (Geary, 1990; Geary & Brown, 1991). One likely reason for this is that gifted children have a more mature long-term memory network for basic math facts resulting in fast and accurate retrieval (Geary & Brown, 1991). These findings suggest that children who can quickly and accurately use cognitive strategies and retrieval are more likely to perform well on achievement tests.

This has implications for gender differences in mathematics achievement in that there is emerging evidence that boys and girls differ in the types of strategies that they use to solve mathematics problems. By the middle of the first grade boys are more likely than girls to retrieve answers accurately whereas girls are more likely than boys to use counting strategies that utilize manipulatives to solve arithmetic problems (Carr & Jessup, 1997; Carr, Jessup, & Fuller, 1999). Research by Fennema et al. (1998) replicated these findings and found gender differences continuing into the second and third grades. Gender differences in strategy use are also evident in older students indicating a pattern of gender differences that extends through high school and college (e.g., De Lisi & McGillicuddy-De Lisi, 2002).

Furthermore, first grade boys have been found to be more variable than first grade girls in their correct use of retrieval strategies indicating that boys might be more likely to be among those identified as highly gifted in mathematics (Carr & Davis, 2002). In this study, we examined whether different strategies differentially predicted mathematics competency. If cognitive strategies are more likely to be used by boys and are evidence of higher level conceptual structures or precepts, then the relationship between cognitive strategy use and mathematics competency should be stronger for boys.

1.2. Spatial ability and achievement

Models of mathematical skills development assume that the spatial processing of information is an important aspect of the development of mathematics expertise (e.g., Kieren, 1993) and is correlated with mathematics achievement (Battista, 1990; McGee, 1979). It has been suggested that spatial ability comes into play in problem solving as problems become more complex by providing a means of simultaneously and holistically representing the different components of the problem (Kaufmann, 1985). In particular, it appears to be the construction of schematic images that include essential information and omit unessential details that is critical for mathematics achievement (Hegarty & Kozhevnikov, 1999).

Although spatial ability takes a number of forms including spatial perception, mental rotation, and spatial visualization, gender differences have been found only for two- and three-dimensional mental rotation (Linn & Petersen, 1985; Voyer, Voyer, & Bryden, 1995). The ability to mentally rotate information may make it easier to integrate and manipulate information in mathematics problems. With regard to word problems, where gender differences are common, spatial ability is thought to improve students' ability to integrate information to form a holistic representation of the problem (Booth & Thomas, 2000). In line with this, boys' advantage on algebraic word problems, word problem solving and arithmetical reasoning is correlated with spatial ability (Geary, Saults, Liu, & Hoard, 2000;