Learning and Individual Differences 47 (2016) 182–193

Contents lists available at ScienceDirect

Learning and Individual Differences

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

Mathematics confidence, interest, and performance: Examining gender patterns and reciprocal relations

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ARTICLE INFO

Article history:
Received 23 January 2015
Received in revised form 4 December 2015
Accepted 7 January 2016

Keywords:
Gender differences
Math confidence
Math interest
Math achievement
Reciprocal relations

ABSTRACT

With data from the Early Childhood Longitudinal Study, Kindergarten Class of 1998–1999, this study explores gender-related patterns in math attitudes and achievement. Following 7040 students from 3rd to 8th grades, we examined gender differences in math confidence, interest, and performance and examined relations among these variables over time. Results indicate that gender differences in math confidence are larger than disparities in interest and achievement in elementary school. Structural equation models show that math performance is a consistent predictor of later confidence and interest, and there is some evidence for a reciprocal relation between confidence and performance in middle school. Relations were generally similar for boys and girls. Results raise questions about the notion that early gender differences in math interest are a driver of disparities in later math outcomes and instead suggest that math interventions for girls should begin early and include attention to math confidence, in addition to achievement.

1. Introduction

Mathematics continues to serve as a "critical filter," rewarding successful students with high occupational status and pay (Campbell, 1991; Sells, 1980; Stinson, 2004). Although gender disparities in K-12 math achievement tend to be small, these disparities precede more substantial differences in students' career choices (Dey & Hill, 2007; Lindberg, Hyde, Petersen, & Linn, 2010). Women continue to be underrepresented in many math-related fields, leaving disproportionate numbers of women in lower-paying occupations (Dey & Hill, 2007; National Science Foundation, 2009; Snyder & Dillow, 2011).

Gender differences in career choices are much larger than those in math achievement, and thus other factors must also be related to career choices (Ceci, Williams, & Barnett, 2009; Kimmel, Miller, & Eccles, 2012; OECD, 2014). Research suggests that both math confidence and interest predict later career choices (Correll, 2001; Riegle-Crumb, Moore, & Ramos-Wada, 2011; Watt et al., 2012). Hence, it is important to investigate when gender differences in math achievement, confidence and interest develop, and how these factors relate to each other as students progress through the critical years of elementary and middle school, when their career aspirations are developing (Maltese & Tai, 2010; Tai, Liu, Maltese, & Fan, 2006).

Although prior studies have examined relations between math attitudes and achievement, additional studies are needed that: (1) examine these relations over a long period of time, (2) incorporate both math confidence and interest, (3) include younger students, and (4) include large U.S. samples. In the present study we fill these gaps by using a nationally-representative, longitudinal sample of U.S. students to explore the magnitude of gender differences in math confidence, interest, and achievement in third, fifth, and eighth grades, as well as the reciprocal relations among these variables over this time period. We also consider possible gender differences in these relations. Understanding how these constructs are related over time can help educators know if they should specifically target students' confidence or interest, if it will naturally follow if we raise students' achievement, or if we need to address confidence, interest, and achievement because they are mutually reinforcing.

1.1. Gender differences in math achievement

Reports conflict about whether gender differences in math achievement are persisting or waning. Some research suggests gaps are narrowing. For example, in a meta-analysis published in Hyde, Fennema, and Lamon (1990) found that the total mean effect size for gender was relatively small ($d = 0.20$); however, in a meta-analysis published in 2010, Lindberg and colleagues found that the overall effect size had diminished even further ($d = 0.07$). Analyses of NAEP data indicate small but persistent gender gaps in scores, averaging roughly 0.10 standard deviations (e.g., Ansell & Doerr, 2000; Lubienski, McGraw, & Strutchens, 2004; McGraw, Lubienski, & Strutchens, 2006). However, analyses of the Early Childhood Longitudinal Study, Kindergarten Class of 1998–1999 (ECLS-K) indicate that gender gaps in math achievement—although absent

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http://dx.doi.org/10.1016/j.lindif.2016.01.002
1041-6080/

when students begin kindergarten—develop during the early elementary years, with disparities of up to a quarter of a standard deviation favoring boys by third grade (Fryer & Levitt, 2010; LoGerfo, Nichols, & Chaplin, 2006; Robinson & Lubienski, 2011).

A critical point to consider when examining these patterns is that research suggests gender differences in math achievement tend to be smaller when assessments contain few complex items (Gibbs, 2010) and are closely tied to the school curriculum, such as on state tests and school grades (Corbett, Hill, & St. Rose, 2008; Catsambis, 1994; Pomerantz, Altermatt, & Saxon, 2002; Willingham & Cole, 1997). For example, Hyde, Lindberg, Linn, Ellis, and Williams (2008) found little to no gender difference in performance on 10 state tests, which are designed to assess whether students have (or have not) met specific curricular standards. In contrast, the ECLS-K assessment, where there are more substantial gender differences, is not tied to any local curriculum and is designed to more accurately pinpoint students' mathematical knowledge using an IRT-based, two-stage adaptive design.

There are several reasons to attend to even small gender disparities in elementary and middle school math outcomes. First, unlike gaps based on socioeconomic status (SES), race, or most other demographics, gender gaps in math achievement and other outcomes cannot be explained by differential access to high-quality schools or teachers, given that boys and girls are fairly evenly distributed within and across schools. Second, in contrast to the gender gap in early reading performance that favors girls and narrows over time (Robinson & Lubienski, 2011), gender gaps favoring boys in math grow across the early school years (Gibbs, 2010). Third, early-but-small differences in math achievement precede stark disparities in math-related career paths (e.g., Ethington, 2001; Riegle-Crumb et al., 2011) and as a result, the gender gap in pay (Dey & Hill, 2007; Snyder & Dillow, 2011).

Because gender differences in math-related career choices are larger than gaps in math achievement would seem to warrant (Kimmel et al., 2012; Riegle-Crumb, King, Grodsky, & Muller, 2012), there are clearly factors other than math achievement that contribute to these disparities. Many scholars emphasize the importance of understanding the role of students' attitudes in shaping math achievement and career choices (e.g., Forgasz, Leder, & Kloosterman, 2004; Halpern, Wai, & Saw, 2005; Hyde, Fennema, Ryan, Frost & Hopp, 1990; Meece, Glienke, & Burg, 2006; Wood & Eagly, 2002). It is important to study student attitudes because there are often gender differences in these attitudes (e.g., Else-Quest, Hyde, & Linn, 2010; Köller, Baumert, & Schnabel, 2001) and research shows they are related to math achievement and career choices (e.g., Riegle-Crumb et al., 2011). In the current study we focus on both confidence and interest in math. Noddings (1998) has argued that girls are simply less interested than boys in math—that is, perhaps society should simply value the careers that girls *are* interested in and not push them to pursue math-related careers if they are not interested in them. Examining the development of gender differences in interest is critical to understanding whether this explanation is likely. In the current study, our focus is on gender differences in math confidence[1], interest, and achievement, including the extent to which gaps are present in elementary and middle school, and how these three constructs predict each other over time.

1.2. Gender differences in math confidence and interest

International data from both TIMSS and PISA reveal that boys express more positive attitudes toward math than do girls in almost all participating countries (Else-Quest et al., 2010; Ginsburg, Cooke, Leinwand, Noell, & Pollock, 2005; Liu, 2009; OECD., 2013; OECD., 2014). Researchers around the world have found gender differences in the two key attitudinal variables considered in this study: math confidence and interest.

In regard to math confidence, numerous studies have found that girls are less confident in their math abilities than are boys (Else-Quest et al., 2010; Herbert & Stipek, 2005; Hyde, Fennema, Ryan et al., 1990; Marsh & Yeung, 1998; Watt, 2004). These relatively lower levels of math confidence have been documented even in samples of students in which girls obtain higher math grades than boys (e.g., Marsh & Yeung, 1998; Pomerantz et al., 2002). Gender differences in math confidence were found as early as first grade in one longitudinal study, though this difference decreased over the course of schooling (Fredricks & Eccles, 2002; Wigfield et al., 1997).

Research on gender differences in interest generally suggests that boys are more interested in math than are girls (Frenzel, Pekrun, & Goetz, 2007; Köller et al., 2001; Watt, 2004). These results are less consistent than those for math confidence, with some studies finding no gender differences in interest (Fredricks & Eccles, 2002; Hyde, Fennema, Ryan et al., 1990). One study found that gender differences in math confidence and interest were similar in size (Watt, 2004), whereas another reported that the gender difference in math confidence was about twice the size of the gender difference in interest (Frenzel et al., 2007). Other work suggests that the gender difference in interest might develop slightly later than the difference in confidence (Lichtenfeld, Frenzel, & Pekrun, 2007). Given arguments that girls might simply be uninterested in math (Noddings, 1998), it is important to understand the point at which girls' interest lags behind that of boys and to consider how it relates to confidence and achievement over time.

1.3. Longitudinal relations among math achievement, confidence and interest

Understanding how math achievement, confidence and interest are related over time can help educators know what they should target. For example, should they specifically target students' math interest because achievement and confidence will naturally follow from enhanced interest, or should they address confidence, interest, and achievement because they are mutually reinforcing?

1.3.1. Reciprocal relations between math confidence and achievement

Much of the literature indicates that there is a positive relation between math confidence and achievement (Eccles & Jacobs, 1986; Ganley & Vasilyeva, 2011; Liu, 2009; Ma & Kishor, 1997; Valentine, DuBois, & Cooper, 2004). However, most of this work does not consider prior achievement and confidence, limiting conclusions about the development of math confidence and achievement in relation to prior confidence and achievement. Conducting longitudinal analyses with data on achievement and confidence at multiple time points can help us to tease apart the direction of the relations.

Theoretically, there are four possible ways in which confidence and achievement could be related to one another: (1) math confidence and achievement are not related, (2) confidence primarily impacts later achievement, or a self-enhancement model (Calsyn & Kenny, 1977), (3) math achievement primarily impacts later math confidence, or a skill development model (Calsyn & Kenny, 1977), (4) math confidence and achievement impact each other, or a reciprocal effects model (Marsh, Byrne, & Yeung, 1999; Marsh & Craven, 2006).

Marsh & Martin (2011) and Marsh et al. (1999) argue that the reciprocal effects model is the most accurate representation, although research findings are mixed: One meta-analysis lends support for a self-enhancement (confidence impacts achievement) model (Ma & Kishor, 1997) whereas two studies with Canadian and Norwegian adolescents, respectively, suggest a skill development (achievement impacts confidence) model (Marsh et al., 1999; Skaalvik & Valas, 1999). However, most existing studies of the relation between

[1] We want to note here that researchers use a number of different terms to describe beliefs about students' own math abilities, and there are some nuances in the definitions of these constructs (e.g., confidence, perceived competence, self-concept, self-efficacy). Many of the items used to measure these constructs are similar and tap into a similar underlying construct, which we refer to simply as "math confidence" throughout this paper for readability.