DIFFERENCES IN MATHEMATICAL ABILITY BELIEFS BETWEEN TEACHERS AND MATHEMATICIANS IN HIGHER EDUCATION

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Existing stereotypical beliefs regarding mathematical ability as being innate and being associated with men more have severe consequences for female students' perceptions of their mathematical ability, their course-taking decisions, and eventually, their decision to enter and stay in STEM fields. Yet how such beliefs compare among educators at different educational stages needs more attention. In this study, we analyzed the beliefs held by K-8 teachers and mathematicians who had or were pursuing a doctoral degree in mathematics regarding whether mathematical ability is innate. We found significant differences between mathematics teachers and mathematicians in their beliefs about mathematical ability and in the underlying structure of their responses.

Keywords: teacher beliefs, mathematics ability beliefs, gender-specific ability beliefs

Gender disparities persist in the representation of women in mathematically intense STEM fields (National Center for Education Statistics, 2013; National Science Foundation [NSF], 2015). Some research has explored the extent to which these gender differences can be explained by widely held stereotypical beliefs and biases that are communicated to girls at an early age in social environments, harming their self-perceptions and academic performance (e.g., Rosenthal & Jacobson, 1968; Steele & Aronson, 1995; also see Ceci, Williams, & Barnett, 2009 and Wang & Degol, 2017, for reviews). Exposure to gender-specific beliefs and implicit biases is hypothesized to reinforce stereotypes that affect women's feelings of competency (or self-concept) in a specific domain (Correll, 2001; Greenwald et al., 2002), potentially dissuading them from pursuing careers in that domain. Thus, it is important to explore potential implicit and explicit messages students receive throughout their academic lives, especially from their teachers during elementary and secondary education as well as their instructors in postsecondary education, given that teachers' and instructors' opinions can have a substantial impact on their self-concept. As such, the objective of this study was to measure and compare teachers' and mathematicians' beliefs about mathematical ability.

To date, little research has compared stereotypical beliefs held by instructors at different stages of education. Prior studies have found that K-12 teachers' conceptions play a role in shaping their actions (for foundational studies, see Cooney, 1985; Ernest 1989; Thompson, 1984; 1992), that elementary and middle-school teachers sometimes believe that mathematical ability is fixed and innate (Copur-Gencturk, Thacker, & Quinn, in press; Chrysostomou & Philippou, 2010), they associate innate mathematical talent with boys more often than girls (Authors, 2019; Fennema, Peterson, Carpenter, & Lubinski, 1990; Tiedemann, 2000, 2002), and they stereotype mathematics as a male domain (see Li, 1999, for a review)—stereotypes that are also associated with those held by their students (Keller, 2001). As students transition from secondary to postsecondary education, young women aspiring to pursue STEM careers continue to be exposed to messages conveying that mathematical ability is innate (e.g., Leslie, Cimpian, Meyer, & Freeland, 2015; Meyer, Cimpian, & Leslie, 2015). Women also receive overtly gender-biased messages from their professors about their mathematical ability (Robnet, 2016) that may lead to gender differences in STEM self-concept (Boysen, 2009; Sax, 1994), suggesting that stereotypical messages might be passed on from professors and internalized by students through personal interaction. However, based on the existing evidence, it is difficult to assess how professors' beliefs compare with those of elementary and middle-school teachers given that few studies have directly measured professors' beliefs about mathematics, and those that do use scales that differ from the ones used at the elementary and middle-school levels.

Current Study

In the present study, we used the same set of questions with two different populations—K-8 mathematics teachers and mathematicians at universities—to investigate what beliefs these two groups held about mathematical ability and how their beliefs compared with one another. To our knowledge, no studies have compared whether the beliefs held by teachers at these different grade levels are different. We aimed to answer the following two research questions:

1. What are mathematics teachers' and mathematicians' beliefs regarding the role of raw ability, hard work, and gender in students' mathematical success?
2. How similar are the constructs underlying the responses of K-8 teachers and mathematicians to these questions about mathematical ability?

We leveraged the existing data gathered by Leslie and colleagues (2015) and then adapted the items used in their study to capture K-8 teachers' beliefs on the same issues. We argue that knowing the kinds of messages students receive across their academic lives has important implications for recognizing female students' perceptions of their ability and their available career trajectories.

Methods

We used existing data from the study by Leslie and colleagues (2015) along with a new data set we created from the survey responses of K-8 teachers. Leslie and colleagues distributed an online survey to experts across 30 disciplines from nine universities in the USA. Of this wider sample, 1,427 mathematicians were contacted, and 133 of them provided usable data (9.3%). Mathematicians were graduate students (45%), postdoctoral researchers (12%), and faculty members (43%) who were mostly female (83%. With regards to K-8 teachers, we collaborated with the Consortium for Policy Research in Education (CPRE) to send out our survey items to elementary and middle school teachers in a large school district in the USA. We restricted our analytical sample to those teachers who reported teaching mathematics and who answered all the survey items, which resulted in 412 teachers. Teachers were mostly female (89%), and taught grades K-2 (45%), grades 3-5 (38%) and grades 6-8 (17%).To make the comparison meaningful between the two groups, we revised the wording of the items used by Leslie and colleagues (2015) to make them relevant to elementary and middle school contexts (see Table 1 for original and updated items).

Analytical Approach

To answer the first research question, we examined descriptive statistics for each group separately and then ran independent *t*-tests for each item to investigate whether the differences in mean scores for these two groups were statistically significant. To answer our second research question, we explored and tested several factor model structures separately for each group to identify which structure fit the data better.

Results

We began by summarizing teachers' and mathematicians' responses to the survey items. As shown in Table 1, the survey responses indicated significant differences between mathematics teachers and mathematicians in their agreement with the statements that (a) being a top student in mathematics requires innate ability that cannot be taught, (b) innate ability is needed to be successful in mathematics, (c) that anyone can become a top student or scholar in mathematics with the right amount of effort and dedication, and (d) that males are more better at/more suited for mathematics than girls. Significance was Bonferroni corrected (α = .05/5).

Table 1: Descriptive Statistics for the Item Responses of Mathematics Teachers and Mathematicians

	Mathematicians			Mathematics teachers				
Individual items	Mean (SD)	Min	Max	Mean (SD)	Min	Max	*t*	*p*
V1. Being a top student (scholar) of mathematics requires a special aptitude that just can't be taught	4.84 (1.78)	1	7	2.41 (1.40)	1	7	16.3	**<.0001**
V2. If you want to succeed in mathematics, hard work alone just won't cut it; you need to have an innate gift or talent	4.52 (1.74)	1	7	2.14 (1.18)	1	7	17.9	**<.0001**
V3. With the right amount of effort and dedication, anyone can become a top student (scholar) in mathematics	3.15 (1.88)	1	7	5.56 (1.50)	1	7	15.1	**<.0001**
V4. When it comes to mathematics, the most important factors for success are motivation and sustained effort; raw ability is secondary	4.44 (1.82)	1	7	4.81 (1.61)	1	7	2.22	.033
V5. Even though it's not politically correct to say it, boys are often better at mathematics than girls (men are often more suited than women to do high-level work in mathematics).	2.23 (1.69)	1	7	1.84 (1.22)	1	7	2.92	**.004**

Note. N = 133 for mathematicians, and N = 413 for mathematics teachers. To account for multiple tests, significance was Bonferroni corrected at α = .05/5. Item text that appears in parentheses indicates the version given to mathematicians.

To answer our second research question regarding the factors underlying these two groups' responses, we explored the same two-factor model for these five items in both mathematician group and mathematics teacher group, given that beliefs about innate mathematical ability and gender ability seemed to be two theoretically different constructs. Thus, we expected that in the two-factor model, the first four items (V1–V4) would load onto the first factor because they were designed to capture mathematics as a discipline that requires raw aptitude, and we expected the fifth item (V5) to load onto the second factor because it was designed to measure beliefs about gender-specific mathematical ability. An exploratory factor analysis (EFA) for the mathematicians' data supported the two-factor model structure. Conducting the EFA with two factors and a promax rotation (i.e., the factors were allowed to correlate), the factor loadings of the five items (V1–V5) on the first factor were 0.726, 0.765, 0.709, 0.746, and 0.014, and the factor loadings of the five items on the second factor were 0.032, 0.081, –0.031, –0.084, and 0.994. On the basis of the results of the EFA, we performed a confirmatory factor analysis (CFA) with the data from mathematicians, in which V1–V4 loaded onto the first factor and V5 loaded onto the second factor. The two-factor model fit was good for the mathematicians' data (CFI = .996; RMSEA = .033; SRMR = 0.032). The factor loadings on V2–V4 were 1.050, 1.000, and 0.987 (Bentler, 1990; Hu & Bentler, 1999).

We attempted to fit the same two-factor model to the mathematics teachers' data, but the model fit was poor (CFI = .692; RMSEA = .213; SRMR = 0.109). Because the same structure was not valid in both groups, the configural invariance test failed. This result implies that the mathematics teachers' data had a different structure. We then conducted an EFA of the mathematics teachers' data to explore the structure of the data. Only the first two eigenvalues were larger than 1 (i.e., 1.99 and 1.28), and a relatively large drop occurred after the first two factors. Therefore, with an EFA of two factors and a promax rotation, the factor loadings of the five items (V1–V5) on the first factor were 0.743, 0.652, 0.008, 0.043, and 0.493, and the factor loadings of the five items on the second factor were 0.021, 0.006, 0.995, 0.468, and –0.071. According to the results of the EFA, V1, V2, and V5 should load onto the first factor, and V3 and V4 should load onto the second factor. To confirm this structure, a CFA was conducted, and the model fit was good (CFI = .994; RMSEA = .034; SRMR = 0.021). The factor loadings of V2 and V5 onto the first factor were 0.710 and 0.525, and the factor loading of V4 onto the second factor was 0.650 (for model identification, the factor loadings of V1 and V3 were constrained to 1). Thus, the two items emphasizing the raw talent needed for success in mathematics and the item associating boys with higher mathematical ability formed one construct, whereas the two items emphasizing the role of hard work and dedication in mathematical success formed another scale for mathematics teachers.

Discussion and Conclusions

These results show that mathematics teachers and mathematicians seemed to hold different sets of beliefs regarding mathematics requiring innate ability, the role of hard work in success in mathematics, and female students' mathematical ability. Furthermore, the underlying structure for these two groups was not identical. The mathematicians seemed to think that mathematics required ability and hard work and that dedication would not lead to success; however, they also did not consider this ability as belonging only to men. In contrast, teachers seemed to differentiate effort and dedication as constructs separate from innate ability. Unlike mathematicians, K-8 teachers did not agree that mathematics was a subject requiring innate ability. Rather, they seem to think that hard work and dedication could lead to success in mathematics.

As mentioned, students' academic self-concept is shaped by the messages they receive from their social environment. Thus, our study suggests that students may be receiving mixed messages from their environments, which could contribute to changes in their self-concept at different stages of their education (e.g., Robnett, 2016; Sax, 2008; Wigfield et al., 1997). The elementary and middle school teachers seemed more likely to agree that mathematical ability is a malleable construct and that effort and hard work could lead to success in mathematics, whereas the mathematicians seemed to believe ability played a key role in success in mathematics. This finding, showing that elementary teachers' and mathematicians' beliefs were different, might explain why gender differences in self-concept shift and expand after elementary school and into postsecondary education, although causal evidence of this link is still needed. Additionally, such potentially drastically different messages between these two groups might severely affect students' self-concept in college, which could explain their shifting majors (e.g., Seymour & Hewitt, 1997). However, more research is needed on the impact of these different and contrasting messages on students' self-concept at different stages of their education. Our study suggests that close attention needs to be paid to the messages teachers and college instructors send so that female students avoid entering or have difficulty staying in STEM-related fields because of stereotypical beliefs their educators may have held.

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