Proposal for Warsaw Partnership

Bold Problem Solving: A New Construct for Improving Mathematics Achievement & Equity

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Preferred Format: On-site in Warsaw

Accompanying Paper for Online Discussion? Yes, a paper on the gender and bold problem-solving study will be available by early spring.

Abstract: Despite U.S. math education reformers' calls for helping all students become autonomous, innovative problem solvers, many challenges remain. There is much we do not yet know about the development of students' problem-solving approaches and whether these approaches by demographics. This presentation will introduce a new construct, "Bold Problem Solving," which refers to students' tendency to approach novel problems in inventive ways, as opposed to adhering to teacher-given procedures. Progress and dilemmas in measuring bold problem solving will be discussed, along with evidence of strong links between a new survey measure of bold problem solving and gender differences in math problem solving performance in one high-achieving sample. Further research on bold problem solving in the U.S. and elsewhere could inform efforts to pursue socioeconomic and other forms of equity, and to enhance students' mathematics outcomes, more generally.

Description of Study

Over the past few decades, U.S. math education reformers have called for strengthening problem-solving skills and mathematically empowering all students. Despite gains in U.S. math achievement, much work remains (Leder & Lubienski, 2015). There may be parallel concerns about students' math problem solving skills in Poland, as the gaps between Polish students and top-scoring PISA nations are larger on nonroutine problem solving than on other math skills (Bodewig, et al., 2015).

In addition to general concerns about students' problem-solving skills, there are persistent differences in U.S. math outcomes by gender. For example, U.S. girls get better grades than boys, but boys outnumber girls 4 to 1 at the 99th percentile by Grade 3 (Fryer & Levitt, 2010). This is particularly troubling, given that future mathematicians and scientists tend to emerge from the top of the achievement distribution, and women still earn less than 20% of engineering, physics and computer science bachelor's degrees in the U.S. (NSF, 2017). Similarly, Polish girls often get better grades than boys, but males are overrepresented at the top of the achievement distribution on the basic-level Matura exam for secondary school students (Zawistowska, 2017).

Overall, gender disparities not only limit important occupational opportunities for women, they diminish the pool of high-quality students who can contribute to math-intensive fields. Strong mathematics problem solving skills are critical for excelling in mathematics, and new measures are needed to help us understand the development of students' problem-solving skills.

Bold Problem Solving

My current research involves defining and studying *"Bold Problem Solving,"* which involves *approaching novel math problems in inventive, non-algorithmic ways*. This construct is designed to capture important gender differences in problem solving approaches that prior researchers have uncovered. For example, researchers have found that girls are more likely than boys to follow teacher-given procedures to solve math problems instead of using invented strategies, such as "work backward" and mental shortcuts (Che, Wiegert, & Threlkeld, 2012; Fennema et

al.,1998; Gallagher, 1992; Gallagher et al., 2000; Goodchild & Grevholm, 2009; Hornburg, Rieber & McNeil, 2017). This relates to analogous findings in science and computing, suggesting girls are less likely to "tinker" than are boys (Jones, et al., 2000). Girls' compliant behavior may boost their math grades, but could have long-term drawbacks as girls encounter increasingly complex math problems in later years (Lubienski & Ganley, 2017).

Research Questions

Given the potential importance of bold problem-solving skills, and persistent gender differences at the top of the achievement distribution, my research team recently set out to examine the following questions (Lubienski, Miller, Makowski & Timmer, 2017):

RQ1. Can we create a reliable survey measure of bold problem-solving approaches?

RQ2. To what extent might this measure explain gender gaps in math performance at the top of the achievement distribution?

Method

Data Collection. We drafted eight survey items to capture students' tendency to use bold problem-solving approaches. Examples include:

- *I prefer inventing my own ways to solve math problems instead of applying procedures my teacher or textbook shows me.*
- *When I am stuck on a math problem, I usually play around with the problem for a while before examining worked examples or seeking help.*

(Note: Response scale ranged from 1=strongly disagree to 5=strongly agree.)

Given that math gender gaps are largest among high achievers, and given that middle school is a formative time for shaping students' career paths, we administered the items to 76 high-achieving 8th graders in a high school affiliated with a large, Midwestern university. In this sample, gender differences in prior math standardized test scores were insignificant. We administered a set of 5 SAT items on which previous gender differences were found (Gallagher, 1992), along with surveys regarding math beliefs and attitudes, and a 3-D Mental Rotation Test (Peters et al., 1995, based on Vandenberg & Kuse, 1978).

Data Analysis. Factor and reliability analyses were used to examine the coherence of the bold problem-solving items, and a t-test was used to examine gender disparities on the resulting scale. We examined whether the new bold problem-solving measure helped explain gender disparities on the SAT items via path analyses in MPlus, with sex predicting problem-solving performance, and with bold problem solving and mental rotation skills as potential mediators.

Results

RQ1. Can we create a reliable survey measure of bold problem solving tendencies?

Results of the analyses revealed that two of the eight "Bold Problem Solving" items fit less well with the others, both statistically and conceptually. The remaining six items cohered as one factor, with Cronbach's alpha = .71. (Details on all items will be provided in the presentation and paper). We averaged the six items and considered the resulting scale sufficiently reliable for use in initial studies, with hope of ultimately refining and testing the items more broadly.

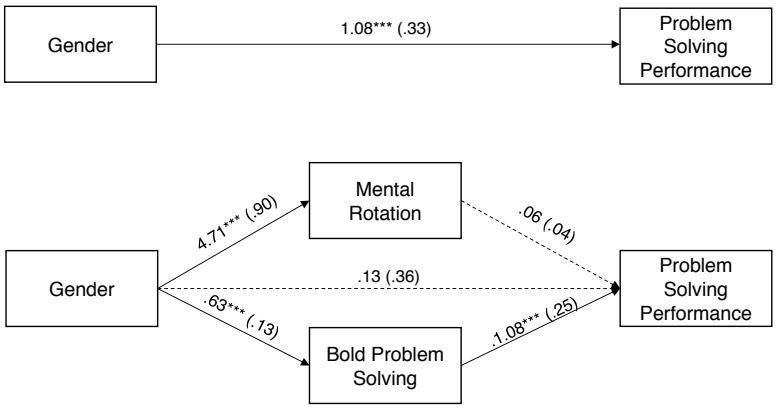
RQ2. To what extent might this measure explain gender gaps in math performance at the top of the achievement distribution?

There were striking sex differences on the new bold problem-solving scale (d=1.09), mental rotation (d=1.18), and performance on the five SAT items (d=.75). Students' bold problem-

solving approaches correlated strongly with students' reported math confidence, spatial skills, and use of mental math.

Results of the path analysis suggest that boys' greater use of bold problem-solving strategies does, indeed, mediate the sex difference in problem-solving performance in this sample. In fact, the relationship between gender and problem-solving performance is no longer significant when conditioning on spatial skills and bold problem-solving (see Figure 1), largely due to the strong relationship bold problem solving holds with both gender and problem-solving performance (p<.001 for both). Results hold when we covary out prior SSAT verbal and math scores.

*Figure 1: Path Analysis Results (****p*< .001)



Future Directions

We plan to refine the bold problem-solving measure (increasing the scale's internal consistency above the current α=.71) and to further validate the measure by linking observed problem-solving approaches (e.g., in think-aloud interviews) to students' self-reported approaches. We also plan to examine this new construct with a broader sample, including an examination of socioeconomic status (SES) differences on the bold problem-solving scale.

Socioeconomic gaps in school performance are stark and growing in the United States (Reardon, 2011). Similarly, there are larger-than-average gaps in math and reading PISA performance between wealthy and poor students in Poland (Bodewig, et al., 2015). There is reason to think that students' problem-solving approaches may differ with SES. For example, national data in the U.S. reveal that lower-SES students are more likely than higher-SES students to view math as "mostly memorizing facts," and to lack exposure to nonroutine problems in their math classrooms (Lubienski & Crockett, 2007). Research also suggests that lower-SES parents and schools are more likely to emphasize obedience to authority over child reasoning and autonomy (Anyon, 1981; Heath, 1983; Lareau, 2002). Hence, our future research on bold problem solving will include attention to SES, as well as gender.

Potential Areas of Future Collaboration with Faculty from UW SoE

I am interested in both small- and large-scale studies of gender and socioeconomic equity, mathematics problem solving, and mathematics education reform/policy. I can envision comparing Polish and U.S. students' responses on the bold problem-solving measure, examining whether gender and SES patterns are similar. I also have expertise in U.S. national datasets that may facilitate collaborations around national data analyses.

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