GENDER DIFFERENCES IN NUMBER STRATEGY USE FOR STUDENTS SOLVING FRACTION STORY PROBLEMS

Cassandra Quinn
University of Missouri
cdquinn@mail.missouri.edu

Susan B. Empson
University of Missouri
empsons@missouri.edu

Victoria R. Jacobs
University of North Carolina at Greensboro
vrjacobs@uncg.edu

Gender differences in fourth and fifth grade students' strategy use for a fraction story problem were investigated using multinomial logistic regression on a sample of 193 written student strategies. Gender was not a significant predictor of type of strategy used, in contrast to earlier studies finding that boys tended to use more abstract strategies whereas girls tended to use more concrete strategies or the standard algorithm.

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Gender differences in mathematics have long been a topic of study in mathematics education (Fennema, 1974; Leyva, 2017). One particular focus of interest has been gender differences in strategy use, inspired in part by research in which Fennema, Carpenter, Jacobs, Franke, and Levi (Fennema, et al., 1998a, 1998b) found gender differences in students' strategies for story problems. In a longitudinal study with 38 girls and 44 boys in grades 1-3, they found no gender difference in the ability to solve addition and subtraction story problems and multidigit computations, yet significant difference in type of strategy used to solve these problems. Girls tended to use concrete solution strategies. Boys tended to use abstract solution strategies that "reflected conceptual understanding" (p. 11). The researchers argued these results indicated differences in the degree to which girls and boys had developed mathematics understanding.

Fennema et al. (1998a) invited interpretations of the results from four scholars: mathematics educator Judith Sowder; social psychologists Janet Hyde and Sara Jaffee; and feminist philosopher Nel Noddings. Sowder (1998) suggested these gender differences could reflect differences in preferences for explaining one's strategy (e.g., girls prefer to give explanations that are clear for others) and worried that students who use more abstract strategies are more likely to make sense in mathematics and have a better chance at succeeding mathematically. Hyde and Jaffee (1998) cautioned against interpreting female deficits based on findings. They suggested teachers could hold gender stereotypes (e.g., girls are compliant, boys are independent) and that those stereotypes were activated in teachers' interactions with students. Noddings (1998) suggested girls could be less interested in mathematics and noted that society does not show the same concern when boys demonstrate less interest than girls in other activities (such as early childhood education or nursing), which led to a critique of the social structure: "Do we approve of a social structure that values competence in mathematics over competence in child care?" (p. 18).

Other education researchers have also studied gender differences in strategy use (Carr & Davis, 2001; Carr, Jessup, & Fuller, 1997; Carr, Steiner, Kyser, & Biddlecomb, 2008) and framed their findings in a variety of ways. For example, Carr and Davis (2001) examined 84 students' use of strategy under both free and constrained choice. Under free choice, girls chose manipulative strategies while boys chose retrieval strategies, consistent with findings by Fennema and colleagues. Under constrained choice, they found that boys were able to use manipulative strategies, but girls were "not as capable" as boys in using retrieval. In their study, manipulative strategies were considered more concrete and retrieval strategies more abstract. In a cross national study, Shen, Vasilyeva, and Laski (2016) found gender differences in strategy use that mediated accuracy for

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students in the United States and Russia but not Taiwan, suggesting that differences could be attributed to instructional contexts, rather than inherent to girls and boys.

If gender differences in strategy use exist, they might reflect important differences in students' conceptual understanding (Fennema et al., 1996; Sowder, 1998), the enactment of gender stereotypes by teachers (Hyde & Jafeee, 1998), or simply differences in students' interests (Noddings, 1998). Whatever the source, attending to differences in strategy use is important, as they could reflect differences in opportunities to develop conceptual understanding. Further, because potential disparities in strategy use are not visible in standardized tests that do not differentiate between types of strategies used, investigating strategy use on a large scale requires analyses that account for the types of strategies girls and boys use to solve problems.

Building on the early study on gender differences in mathematics (Fennema et al., 1998a), this study investigates gender and strategy use in fraction story problems. Our study is different in important ways. (1) Our analysis is over 20 years after the publication of the study by Fennema and colleagues, and thus provides a glimpse of current gender dynamics in mathematics teaching and learning. (2) Our study is comprised of fourth and fifth grade students solving a fraction story problem, compared to the first, second, and third grade students and a focus on whole-number addition and subtraction in the original study. Like Fennema and colleagues (1998a) and the invited interpretations (Hyde & Jafeee, 1998; Noddings, 1998; Sowder, 1998), we are careful to consider the importance of strategy use and avoid framing these differences as reflective of inherent differences in ability. We investigated these differences for 193 fourth and fifth grade students by asking the following: Are there significant gender differences in strategy use for fourth and fifth grade students solving fraction story problems?

Methods

Sampling and Participants

Data for this analysis came from a larger professional development design study, focused on documenting and supporting the development of teachers' responsiveness to students' fraction thinking during instruction (Jacobs, et al., 2019). As part of this larger study, students from 50 different classrooms were administered a paper and pencil assessment at the beginning and end of the school year, to measure fraction problem solving and conceptual understanding. Items were open response. A rubric for scoring and coding student responses was developed, and for each item, all responses were triple coded until 85% (or higher) agreement was reached among coders, at which point, responses were single coded.

Data Sources and Analysis

For the current study, we focus on one item on the assessment administered at the end of the school year to 562 students, in grades 4 and 5. Of these, 244 student responses were coded as having a valid strategy, which means the student started with the given quantities and operated on those quantities in some justifiable way to reach an answer, and they could include small mistakes. The item consisted of the following story problem: *Allie has 1 6/8 sticks of butter. She needs a total of 5 1/8 sticks of butter to make cookies. How much more butter does Allie need so she can make cookies?*

Each of the responses was coded individually for type of strategy used. For this analysis, we focused on valid strategies (n = 193), including concrete strategies (n = 19), invented algorithms (n = 90), and the standard algorithm (n = 84). Strategies labeled as "other" (n = 24) or "none" (n = 27) were not included because they were not interpretable with respect to the research question. The final sample included 101 girls and 92 boys. These strategy codes and their frequencies in the sample are described and illustrated in Figure 1. Type of strategy served as our dependent variable.

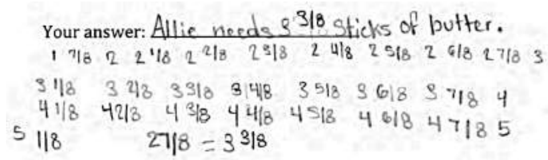
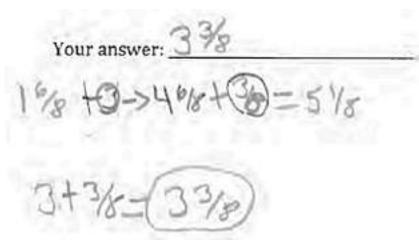
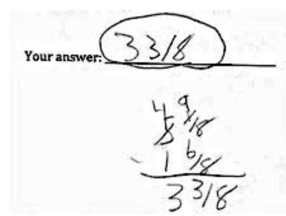
Type of Strategy		Example
Concrete Strategies Girls (n = 10) Boys (n = 9)	*Direct modeling:* strategies that represented all sticks and fractional sticks of butter individually. Usually these were notated with drawings. *Counting up/down by unit fraction*: Strategies that represented each individual group of 1/8 in the count in some way.	 Counting strategy
Invented Algorithms Girls (n = 45) Boys (n = 45)	Computation strategies that decompose the mixed numbers and/or fractions in some way and/or increment or decrement in "hops" (larger than a unit fraction) in some way.	
Standard Algorithm Girls (n = 46) Boys (n = 38)	Standard algorithms for subtraction in which a child uses knowledge of the standard algorithm procedure to determine the missing addend.	

Figure 1: Types of Valid Strategies and Examples Used in the Analysis

Because the dependent variable is categorical, we used multinomial logistic analysis. Concrete strategies and the standard algorithm were separately predicted against the reference category of invented algorithms. We chose invented algorithms as the reference category because if gender differences reflecting conceptual understanding were significant, we would expect to see an over representation of girls in either concrete strategies or the standard algorithm. Using invented algorithms as the reference category allowed comparison of both concrete strategies and the standard algorithm to invented algorithms.

We used three models to analyze students' strategy choice and gender. The first model was used to detect if gender significantly predicted strategy use across grade levels. The second model was used to detect if gender predicted strategy use in fourth or fifth grade. In the third, we added the interaction of grade and gender to the second model.

Results

Results from the statistical models are listed in Table 1. Odds ratios (and standard errors) of the three models show that gender was not a significant predictor of concrete strategy use or standard algorithm use. In the first model, there was some significance in the intercept, meaning students were less likely to use concrete strategies than invented algorithms ($p < 0.001$), but these differences were not based on gender. In the second model, the significance in the intercept remained, and there was some significance in grade level ($p < .05$), meaning fifth grade students were less likely to use concrete strategies compared to invented algorithms. Again, these differences were not based on gender. We included the interaction of gender and grade in the third model and did not detect significance in the interaction.

Table 1: Results of Statistical Models

	Odds ratio (and standard errors)		
Variable	1	2	3
Concrete strategy compared to invented algorithm			
Intercept	0.20 (0.37)***	0.33 (0.40)**	0.36 (0.41)*
Female (compared to M)	1.11 (0.51)	0.99 (0.51)	0.81 (0.58)
Fifth (compared to fourth)		0.22 (0.67)*	0.12 (1.10)
Gender X Grade			3.14 (1.39)
Standard algorithm compared to invented algorithm			
Intercept	0.84 (0.22)	0.64 (0.28)	0.64 (0.34)
Female (compared to M)	1.21 (0.30)	1.27 (0.31)	1.28 (0.45)
Fifth (compared to fourth)		1.63 (0.31)	1.64 (0.45)
Gender X Grade			1.00 (0.62)
	R^2= .00 χ^2 = 0.40, p > .05	R^2= .03 χ^2 = 12.43, p < .05	R^2= .04 χ^2 = 13.18, p < .05

N = 709; *p < 0.05; **p < 0.01; ***p < 0.001

Discussion and Conclusion

The implications of these findings are in the statistical insignificance of the dependent variable. We tested three models related to the research question: Are there significant gender differences in number strategy use for fourth and fifth grade students solving a fraction story problem? Because gender was not significant in any of the models tested, gender-based differences in strategy use were not indicated, a finding that is in opposition to previous findings. However, we focused only on a single item and two grade levels, which limits the scope of our findings. Further, our study was not longitudinal and cannot speculate on trends in development of strategy use and conceptual understanding. Research across multiple assessment items and grades is needed for a more complete examination of students' gender and strategy use in the domain of fractions. Finally, we noted that only 193 of the 562 students used a valid strategy, roughly a third of all students, which suggests that this was a difficult problem for the sample. Research on an item in which a greater proportion of students used a valid strategy is necessary to examine if and for what items the finding holds.

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