GENDER DIFFERENCES IN THE MISSOURI ELEMENTARY MATH CONTEST

David Ashley and Lynda Plymate

1. Background and Introduction. The Missouri Council of Teachers of Mathematics (MCTM) has conducted an annual elementary mathematics contest for students in which school-selected participants compete on tests measuring mathematical concepts and problem solving. Each school or administrative unit is allowed to select its representatives to the contest based on whatever criteria it judges to be fair and professional. The maximum number of students a school may enter at each grade level depends on their enrollment at that grade level, from a minimum of 3 to a maximum of 6. Home-schooled students are also invited to participate as long as they represent a minimum of 10 home-schooled children at the same grade level in their region. The contest has grown significantly over its 16-year history, and it now involves approximately 3300 participants from 450 public and private elementary and middle schools in Missouri each year.

In 1993 the use of calculators and measuring instruments was encouraged for use on both the Concepts and Problem Solving events. This decision was prompted by a desire to have the contest questions more closely align with recommendations from the 1989 National Council of Teachers of Mathematics (NCTM) *Curriculum and Evaluation Standards for School Mathematics* [16]. At both the regional and state level, these two contest events involve 30-minute written exams. The Concepts test assesses knowledge of number and number sense, geometry, measurement, data analysis, probability, and statistics. The Problem Solving test assesses higher order thinking skills, and requires an application of mathematics utilizing both concepts and computation. Any student who places first, second, or third in a regional contest event is invited to enter the same event at the state contest.

Dr. Plymate served as statewide director of the MCTM contest from 1994 through 2000; Dr. Ashley joined the effort in 1999 and assumed the directorship in 2000. At the state finals competition we consistently observed a significant difference in the number of male winners compared to female; both in eligibility as regional winners and in the number of winners at the state level. We could not avoid being curious as to why males so consistently outperformed females on this contest. Are male students in Missouri actually learning more mathematics than females, or are the contest questions gender biased? Alternatively, are males spending more time preparing for the contest, or is the selection process at the local schools gender biased?

Prior studies address some of these questions. The Third International Mathematics and Science Study (TIMSS, 1998) indicated that in the United States there were few differences in mathematics perfomance between 4th grade females and males. The few exceptions noted were in the areas of measurement, estimation, and number sense where males had significantly higher achievement than females. The TIMSS reported no significant differences in performance between 8th grade females and males. In addition, the National Assessment of Educational Progress (NAEP, 2000) reported no significant differences between genders at the 4th grade level. On this test, males outperformed females at the 8th and 12th grade levels; however, the gap between average scores at all grade levels was quite small and had fluctuated only slightly in the last ten years. Missouri's 4th and 8th graders performed at the national average on the NAEP test. Using these two major studies as a basis, we should have expected no significant differences in mean achievement between genders at MCTM's Elementary Math Contest at either the regional or the state level. Are gender issues different for mathematics contests than for mathematics learning nationwide?

Differences in socialization of the genders, particularly with regard to contests, is also addressed in the literature. Nichols and Kurtz [19] reported that the dominance of males in mathematical contests can discourage females from pursuing their interest in the subject. Hanson [10] found that by the second grade students have already identified math and science as "male". She also found that young females gain less experience than males with core math concepts due to the kinds of toys geared toward each gender. By third grade, females rated their own competence in mathematics lower than that of their male classmates, even when they received the same or better grades. Volpe [28] found, however, that sixth grade females involved with a Math Olympiad team reported confidence in their abilities as mathematicians, and that they took more risks in problem solving. These studies suggest reasons why we should expect fewer female participants in the contest, however, they also tell us that those females that do participate should do just as well as their male counterparts. Obviously, further research and investigation was needed.

2. Data Collection and Analysis. Having informally observed gender differences at previous year's state competitions, we decided to formally investigate these differences during the year 2000 contest. A ten-item survey instrument was constructed and sent to all regional participants to verify gender and determine methods individual participants were using to prepare for the regional contest. A thirty-item survey was also constructed and sent to all parents or guardians of regional winners preparing to go to the state contest. This survey was designed to verify methods used by the schools to select their participants and methods used by successful students in preparing for the contest, and to identify the types of support and instruction winning students received.

Regional exam results from the top ten finishers in each event were collected for analysis. At the state contest all exam results were collected for analysis. Each exam question was analyzed to determine which of the NCTM [17] content areas were being assessed: numbers and operations, algebra and algebraic thinking, geometry, measurement, and data analysis and probability. Furthermore, we determined whether each question was structured primarily to assess conceptual or procedural knowledge, and whether it was measuring primarily a concept or a problem solving skill.

We had 3209 students participate at 25 regional sites in the year 2000 contest, representing 436 public and private schools or home-school organizations. There were 1107 fourth graders, 1113 fifth graders, and 989 sixth graders who participated in both testing events at the regional level. Of these, 387 students qualified to participate at the state contest (142 fourth graders, 131 fifth graders, 114 sixth graders) with 131 qualifiying in both events. The number and percentages of participants for which we received data, for both genders and all three grades, is shown in Table 1.

3. Results. There were no significant differences (null hypothesis is not rejected at the .05 level) on how males and females were selected for the contest. Fifty-seven percent took a preliminary test while 43% were selected based on either a math specialist's recommendation, a teacher's recommendation, by the math club, or by some other means. It is interesting that 61% of males were selected from a preliminary exam compared to 51% of females, and a higher percentage of females were selected based on a personal recommendation from their teacher (38%) or the math club (6.1%) than were males (29% and 3.6%, respectively).

There were no significant differences (null hypothesis is not rejected at the .05 level) on how males and females prepared for the contest (75% spent 5–20 hours working with teachers, other students and family members). Interestingly, though perhaps not significant, 8.6% of the regional male population claimed to have done nothing to prepare for the contest, compared to 4.6% of the female population. When preparing for the state competition, the percentage of both male and female students claiming to work with their teachers and other students outside of class increased as the grade level increased.

We expected that more males would be entering the regional contest than females, partially based on our observation of more males at previous year's state contests. This expectation was realized; however, the difference was only 12 percentage points for the regional contests. Schools are selecting almost as many females as males to participate in these regional contests (Table 1). However, in all categories at these regional contests, male participants outperformed female participants, sometimes significantly. As a result, the number of males qualifying to participate at the state contest was 35 percentage points higher than the number of female qualifiers. Male winners at the state level outnumbered female winners by an overwhelming margin, 83 percentage points.

	Male	Female
4^{th}	557	433
5^{th}	571	462
6^{th}	500	391
State Qualifiers		
4^{th}	96	46
5^{th}	93	38
6^{th}	73	41
State Winners (1-10)		
4^{th}	18	2
5^{th}	19	1
6^{th}	18	2

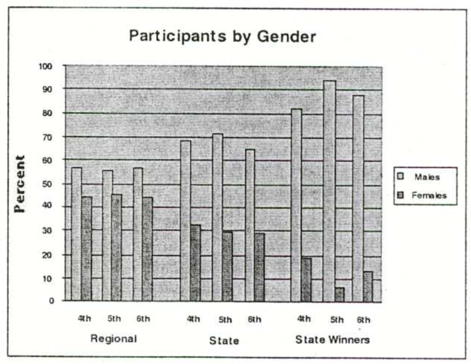

Table 1. Regional and State Participants by Gender

Males outperformed females on regional questions measuring both problem solving skills and concepts, with the difference for problem solving skills being at a two to one margin. However, no significant difference was seen between the genders when assessing conceptual versus procedural knowledge. As seen in Table 2, 6th grade females had more success with numbers and operations on the regional concepts test than males (93.8 versus 59.2% correct). However, for all other tests and all other NCTM content areas, females scored lower than males.

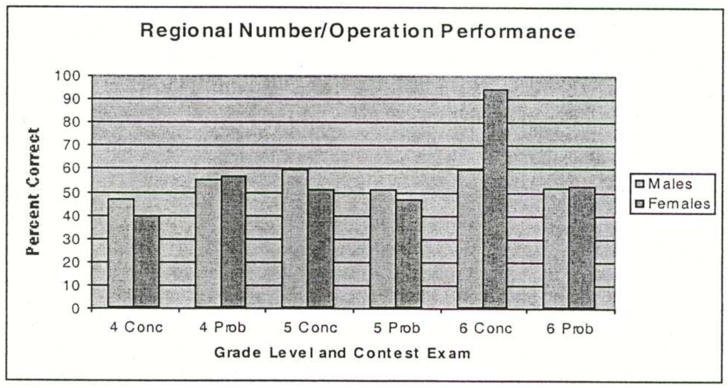

Table 2. Regional Test Results for Number/Operation Performance

Males also outperformed females by a margin of at least 2 to 1 on many of the individual questions on the regional exams. For example, one of seven such problems on the 4th grade concepts test was

> A Model airplane has a scale in which 1 inch represents 15 feet. If the completed model is $15\frac{1}{2}$ inches long, how long is the actual airplane?

Eight of the 24 questions on the 5th grade concepts test were also answered correctly at least twice as often by males as females. At all three grade levels there were at least 4 questions on the problem solving test where this same pattern occurred. One such 6th grade problem was

> Four strips of aluminum, each 50 inches long by 5 inches wide, are arranged in a square. What is the area of the interior square opening, in square inches?

In fact, two-thirds of the male-dominated problems involved problem solving skills rather than knowledge of a concept. Thirty-six percent of the male dominated problems involved numbers and operations, such as the following example from the 5th grade problem solving test:

> What is the smallest positive whole number answer possible when you rearrange the following seven symbols, using each exactly once? $(, x, -,), 9, 2, 4.$

Twenty-seven percent of the male-dominated problems involved measurement. No significant gender differences where found when assessing the students' conceptual knowledge versus their procedural knowledge.

Gender also influenced results for repeating participants, those students who were representing their schools for the second and third time at this contest. For both 5th and 6th grade regional contests, the percent of repeating male participants (38%, 43%) was higher than repeating females (33%, 38%). Forty percent of both 5th and 6th grade state qualifiers had also qualified for the state contest the previous year (45% males, 30% females) with the concepts event having a higher repeat rate than the problem solving event. Forty percent of the 6th grade state qualifers had also qualified for state both of the previous two years (43% male, 32% female).

4. Discussion. Are male elementary students in Missouri actually learning more mathematics than females? Are males more competitive than females? From our results it appears that males may enter the fourth, fifth and sixth grades with stronger mathematics skills than females. The strong gender stereotyping of mathematics and science as a "male" domain, developed by students as early as second grade (Hanson [10]) may explain some of this gender difference. Silverman and Pritchard [25] also found that this stereotyping had not changed when students entered the middle grades, and that it was reinforced by female students' lack of knowledge concerning technological careers and how concepts learned in class related to those careers. Pettitt [22] reports, however, that neither gender recognizes a relationship between the study of mathematics and their future careers.

Carraher, Carraher, and Schliemann [4] offer the alternate explanation that mathematics skills and beliefs develop in response to social and environmental demands. They found that in real world situations, children developed an intuitive sense of how to solve problems. From birth, female infants are discouraged from risk-taking and from exploring the world around them, whereas males are given toys that encourage small motor skills and spatial visualization skills, both necessary for later development in mathematics. Measor and Sikes [14] and Hensel [11] report that even the toys given to male and female babies differ. Males play with bricks, trucks, and climbing apparatus and females play primarily with housekeeping activities. Male children also have increased access to neighborhood activities and resources (Entwisle, Alexander, and Olson [7]). This increased exposure to real world situations for males may also help explain why their achievement scores in mathematics surpass that of females.

Fennema and Carpenter [8,9] found that while third grade males and females had equal abilities when using number facts and operations and other routine mathematics problems, males outperformed females on solving extensions to these routine problems. Males tended to use more abstract solution strategies and were more able to adapt and modify a strategy that had been learned in class than females. Females solved problems from the perspective of interdependence and relationship rather than from an isolated skills analysis viewpoint favored by males [2]. This helps explain why two-thirds of the male-dominated problems in the elementary contest involved problem solving.

Self-confidence (or lack thereof) may also be a strong contributing factor to why males are outperforming females on this contest. Studies point to the importance of confidence in one's abilities to learn mathematics and attribute achievement to that ability. Pajares [20,21] reported that students' confidence to solve mathematics problems is a more powerful predictor of their ability to solve those problems than is their confidence to earn high marks in math-related courses. They suggest that students who believe in themselves put forth greater effort, persistence and perseverance. Hanson [10] reported that by third grade, females rate their competence in mathematics lower than their male counterparts, even when they receive the same or better grades. Working with the beliefs of third graders and junior high school students, Stipek and Granlinski [27] also suggest that males have more positive attitudes and perceptions toward mathematics than females. They report that females have lower expectations for themselves in mathematics and believe they do not have good mathematics ability. Ecceles [6] reported that first, second, and fourth grade females feel more competent in reading and music, whereas males feel more competent in sports and math. By the sixth grade, females see mathematics as less important and useful to career goals than males. These strong social messages of confidence and competence in mathematics may be the reason females are self-selecting out of math-related activities as early as preschool. The mathematics curriculum at middle school emphasizes abstract concepts and spatial visualization, two skills that many females have not had much experience within pre-school and primary levels. The generally lower self-confidence in mathematics experienced by most young females may make them especially vulnerable at this contest.

But why do females have negative or ambivalent attitudes toward mathematics? Jewett [12] points to parental and societal perceptions and teacher behavior and expectations as the main reasons that females select out of science and mathematics. Teachers and parents pass on their likes and dislikes in very subtle ways. Pre-service elementary teachers in our own classes report, through required educational autobiographies, having encountered the same dislike and fear of mathematics in their own schooling.

Karplus, Pulos, and Stage [13] found that student attitudes towards mathematics and performance on reasoning tasks was highest in schools with teachers who had the most positive attitudes toward students and mathematics instruction. Pajares [20] tells us that confident teachers create mastery experiences for students whereas teachers with low instructional efficacy undermine students' cognitive development as well as students' judgements of their own capabilities. Are math-phobic elementary teachers, who are generally female, passing these fears onto their female students? If the teacher plays the central role in developing positive feelings towards mathematics, then teachers who do not like mathematics may likely have students who do not like mathematics.

Barnes [1], Diamond [5], Schwartz and Hanson [24], and Bono [3] all report that the preferred learning style for females is working collaboratively rather than competitively, and that females would enjoy mathematics more and increase their time on task if it were taught in a cooperative setting. Females also respond better to teaching topics that relate to their own lives. They need to be encouraged about their own abilities. Spencer et al. [26] showed that high-achieving females performed significantly worse than males on a standardized math test when the stereotype about their math ability was made salient, such as being outnumbered. It may be that females are self-selecting out of this elementary contest because they do not enjoy competitive events. For those who do elect to participate, perhaps their lower performance is a direct result of the low number of females competing, especially at the state level.

5. Conclusions. This study is still in an early stage, and it would be risky to draw conclusions from data collected in a single year. However, our work so far suggests there are differences between the way students perform on MCTM's Elementary Math Contest versus their performance on the TIMSS and NAEP exams. The participants at MCTM's Elementary Math Contest should be the state's highest achievers in mathematics in their respective grade levels, whereas both the TIMSS and NAEP exams are given to all students. Stereotyping, social demands and lower self-confidence in female participants at the contest may explain some of the gender differences seen in achievement. Perhaps the contest format itself, being an individual rather than collaborative effort, favors a male-preferred and is biased against the female-preferred learning style. Finally, it still must be questioned whether female students are equally prepared to answer questions that are not routine. Do teachers expect the same level of higher learning in mathematics from female as well as male students?

Further analysis of contest results over a five-year period may reveal different patterns than what we saw in the year 2000 contest. Additional questions have been added to the survey instruments to investigate possible links between the self-confidence of our contest participants and their achievement scores. We are also investigating possible links between the belief that mathematics is a male dominated subject and contest participant achievement scores. It is hoped that this study will not only make it possible to identify and correct any gender biases contained in MCTM's Elementary Math Contest, but more importantly support all students in developing confidence in their mathematical competence and increase their love of mathematics. Given that males and females have very different ways of thinking and learning, it is important that we know as much as possible about those differences to be able to provide appropriate gender-unbiased contest events.

References

1. M. Barnes, "Collaborative Group Work in Mathematics: Power Relationships and Student Roles," Paper presented at the Annual Conference of the Australian Association for Research in Education, Adelaide, Australia, Nov. 29–Dec. 3, 1998.

2. S. Blake, "Are You Turning Females and Minority Students Away from Science?" *Science and Children*, 30 (1993), 32–35.

3. D. Bono, *The Impact of Cooperative Learning on Suzy and Janie's Attitudes About Math*, *Research Report in Virginia*, Virginia, 1991.

4. T. N. Carraher, D. W. Carraher, and A. D. Schliemann, "Mathematics in the Streets and in the Schools," *British J. of Developmental Psychology*, 3 (1985), 21–29.

5. J. Diamond, "Sex Differences in Science Museums: A Review," *Curator* 37 (1994), 17–24.

6. J. Eccles, A. Wigfield, R. Harold, and P. Blumenfeld, "Age and Gender Differences in Children's Self and Task Perceptions During Elementary School," *Child Development*, 64 (1993), 830–847.

7. D. R. Entiwisle, K. L. Alexander, and L. S. Olson, "The Gender Gap in Mathematics: Its Possible Origins in Neighborhood Effects," *American Sociological Review*, 59 (1994), 822–838.

8. E. Fennema and T. P. Carpenter, "New Perspectives on Gender Differences in Mathematics: An Introduction," *Educational Researcher*, 27 (1998), 4–5.

9. E. Fennena, T. P. Carpenter, V. R. Jacobs, M. L. Frankle, and L. W. Levi, "Gender Differences in Mathematical Thinking," *Educational Researcher*, 27 (1998), 6–11.

10. K. Hanson, *Teaching Mathematics Effectively and Equitably to Females*, NY: ERIC Clearinghouse on Urban Education, 1992.

11. R. A. M. Hensel, "Mathematical Achievement: Equating the Sexes," *School Science and Mathematics*, 8 (1989), 646–653.

12. T. O. Jewett, "And They Is Us," *Gender Issues in the Instruction of Science*, Southern Illinois University, Edwardsville, IL, 1996.

13. R. Karplus, S. Pulos, and E. Stage, "Proportional Reasoning of Early Adolescents," *Acquistion of Mathematics Concepts and Processes*, R. Lesh and M. Landau (eds.), New York: Academic Press, 1983.

14. L. Measor and P. Sikes, *Gender and Schools*, New York: Cassell, 1992.

15. I. Mullis, M. Martin, A. Beaton, E. Gonzales, D. Kelly, and T. Smith, *Mathematics and Science Achievement in the Final Year of Secondary School*, Center for Study of Testing, Evaluation, and Educational Policy, Boston College, 1998.

16. National Council of Teachers of Mathematics, *Curriculum and Evaluation Standards for School Mathematics*, Reston, VA: NCTM, 1989.

17. National Council of Teachers of Mathematics, *Principles and Standards for School Mathematics*, Reston, VA: NCTM, 2001.

18. National Center for Educational Statistics, *The Nation's Report Card 2000 Mathematics Highlights*, U. S. Department of Education, Office of Educational Research and Improvement, NCES 2001–518, 2001.

19. R. Nichols and V. Kurtz, "Gender and Mathematics Contests," *Arithmetic Teacher*, 41 (1994), 238–239.

20. F. Pajares, Lecture delivered at Emory University, Cannon Chapel, Great Teachers Lecture Series, January 27, 2000.

21. F. Pajares, "Measuring and Mismeasuring Self-Efficacy: Dimensions, Problems and Misconceptions," Paper presented at a symposium chaired by B. J. Zimmerman, Annual meeting of the American Educational Research Association, New York, 1996.

22. L. Pettitt, "Middle School Students' Perception of Math and Science Abilities and Related Careers," Paper presented at the 61st Biennial Meeting of the Society for Research in Child Development, Indianapolis, IN, March 30–April 2, 1995.

23. M. Sadker and D. Sadker, *Failing at Fairness: How Our Schools Cheat Females*, New York: Scribners and Sons, 1994.

24. W. Schwartz and K. Hanson, *Equal Mathematics Education for Female Students*, Educational Developmental Center, Inc., Newton, MA, Center for Equity and Cultural Diversity, 1992.

25. S. Silverman and A. Pritchard, *Building Their Future: Females in Technology Education in Connecticut*, Hartford CT: Connecticut Women's Education and Legal Fund, 1993.

26. S. Spencer, C. Steele, and D. Quinn, "Stereotype Threat and Women's Math Performance," *Journal of Experimental Social Psychology*, 35 (1999), 4–28.

27. D. Stipek and H. Granlinski, "Gender Differences in Children's Achievement-Related Beliefs and Emotional Responses to Success and Failure in Mathematics," *Journal of Educational Psychology*, 83 (1991), 361–371.

28. B. Volpe, "A Females' Math Olympiad Team," *Mathematics Teaching in the Middle School*, 4 (1999), 290–293.

David Ashley
College of Applied and Natural Sciences
Southwest Missouri State University
Springfield, MO 65804
email: dia059f@smsu.edu

Lynda Plymate
College of Applied and Natural Sciences
Southwest Missouri State University
Springfield, MO 65804
email: lsm953f@smsu.edu