GENDER DIFFERENCES IN MATHEMATICS ACHIEVEMENT AMONG GIFTED SECONDARY STUDENTS[1]

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ABSTRACT

This paper examined the gender differences in mathematics achievement among gifted students in Singapore. It focused on the extent to which psychosocial factors such as attitude and attribution could account for the variations in the gender differences. The sample of 362 Secondary 3 and 4 (Grades 9 and 10) students was drawn from participants of a Gifted Education Programme in three single-sex secondary schools. The instruments employed were the SAT-M, the Fennema-Sherman Mathematics Attitude Scales and the Mathematics Attribution Scales. In contrast to most studies, results on the analysis of the SAT-M showed patterns of gender differences favouring the girls. The strengths of the girls lie in content areas such as arithmetic and geometry. Significant gender differences were found in some of the mathematics attitude subscales, with girls attributing their success in mathematics to their ability and effort. Significant predictors in mathematics achievement for the female sample were also found to be confidence and intrinsic motivation in the learning of mathematics. The implications of these findings for the gifted programme were also discussed.

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[1] Paper presented at the 11th World Conference on Gifted and Talented Children, 30 July - 4 August, 1995, Hong Kong

INTRODUCTION

The purpose of this study was to investigate whether gender differences existed in mathematics achievement between male and female secondary gifted students in Singapore and to determine the predictive power of attitude and attribution variables on achievement levels. The topic of gender differences in mathematical ability and achievement has been the interest of many researchers as far back as the 1970's. One of the reasons for the persistent interest is the possible relationship between mathematics performance and academic or career opportunities and accomplishment (Lubinski & Benbow, 1992).

Recent research studies (Feingold, 1988; Friedman, 1989; Hyde, Fennema, Lamon, 1990) produced a complete spectrum of conclusions, ranging from male superiority, no differences, to female excellence. Factors such as the characteristics of the population studied (Benbow & Stanley, 1983; Feingold, 1988; Fennama, Hyde, Ryan & Frost, 1990) and the nature of the instruments used to measure mathematics achievement (Kimball, 1989; Becker, 1990) influence the direction of gender differences. Gender-related differences in favour of males appear to be more pronounced in academically talented populations (Benbow & Stanley, 1980; Benbow, 1988; Durden, Mills & Barnett, 1990).

There is a great deal of gender research with a focus on why differences exist. Studies have focused on cognitive abilities (Pattision & Grieve, 1984) and affective variables such as attitudes and socialisation (Bern, 1981). Findings from these areas promise hope for intervention strategies to improve education for all. The causes to which individual attributes their mathematics successes and failures have been linked to achievement related behaviour (Wolleat, Pedro, Becker & Fennema, 1980; Stipek & Weisz, 1981). Actual performance, affective reactions to success and failure and the subjective probability of future successes and failures have all been associated with particular attributional patterns. Different attributional styles (Wolleat, Pedro, Becker & Fennema, 1980) adopted by males and females can account for the variations in mathematics achievement.

The present study assessed gender differences among the gifted secondary students in Singapore and explored the patterns of such differences. The study also investigated mathematics attitudes and attribution behaviour as possible explanations for gender differences. As male superiority is more pronounced after the onset of adolescence (Hyde, Fenneam, & Lamon, 1990). The study's sample was made up of gifted students from Secondary 3 and Secondary 4 (Grades 9 and 10). Generally, gender studies on the gifted have been very much restricted to children between the sixth to eighth grades. This study hopes to supplement the existing understanding of mathematics achievement between boys and girls among the gifted and to extend the pool of information to include children from the ninth and tenth grades. Mathematics attitude and mathematics attribution variables were selected for analyses to determine the extent to which these variables can predict mathematics achievement.

METHOD

Sample

The sample used for this study was drawn from among secondary students of the Gifted Education Programme (GEP), housed in three single-sex schools. The analysis was carried out on 362 students (142 females, 220 males), aged 15 to 16.

Instruments

College Board's Scholastic Aptitude Test (SAT-M) The SAT-M is developed by the Educational Testing Service in Princeton, New Jersey for 16- to 18-year olds to measure developed mathematical reasoning ability. The SAT-M consists of 40 standard multiple-choice items on arithmetic, algebra, geometry and miscellaneous areas as well as 20 quantitative comparison questions, all to be solved within 60 minutes. Quantitative comparison items require the candidate to examine 2 given sets of data and to decide whether one is equal to, greater than or less than the other quantity. Other questions in the SAT-M require the application of numerical, graphical, spatial symbolic and logical techniques to familiar situations. Cronbach alpha coefficients of pilot tests of the SAT-M in Singapore were 0.845 (sample of girls) and 0.901 (sample of boys).

Fennema-Sherman Mathematics Attitudes Scales (FAS) Fennema and Sherman (1976) designed the instrument for use with high school students. The instrument includes nine 12-item subscales: Mathematics *Anxiety*; *Confidence* in learning mathematics; Perceptions of the *Usefulness* of Mathematics; *Effectance Motivation*; Perception of *Mathematics as Male Domain*; Perception of attitudes of influential persons towards the learner of mathematics: *Father*, *Mother* and *Teacher*; and the attitude towards *Success* in mathematics. Fennema and Sherman reported KR20 values ranging from 0.86 to 0.90 for a norming sample of Grades 9 through 12 students.

Attribution of Success & Failure in Mathematics (MAS) The MAS is a 16-item self reporting questionnaire designed by Elizabeth Fennema, Patricia Wolleat and Joan Daniels Pedro (1979) for use with high school students. Successes and failures can be attributed to 4 possible causes: one's ability, the task undertaken, effort exerted and luck encountered. The MAS is made up of 8 subscales: *Success_Task*, *Success_Effort*, *Success_Environment*, *Success_Ability*, *Failure_Task*, *Failure_Effort*, *Failure_Environment* and *Failure_Ability*. The test manual reported Cronbach alpha values of the subscales ranging from 0.36 to 0.79.

ANALYSIS AND FINDINGS

Raw scores of the SAT-M

The SAT-M test was marked against the given answer key. Table 1 gives the summary statistics and two-tail t-values. The mean number of total correct responses (*SAT*) from the female sample was higher than that from the male sample. There was greater variability in the boys' scores.

Insert Table 1 here

Details in Table 1 showed that the girls did better than the boys in the quantitative comparison items (*Quan*). However, the differences found in quantitative comparison items were small as indicated by the effect size of 0.354. In particular, the girls' strength were in Arithmetic, Geometry and items accompanied by figures and diagrams (*Figure*). In none of the subcategories was the boys' performance superior to the girls'. In the Miscellaneous category where the items were not directly related to topics taught in the classroom, there were significant gender differences favouring the girls at the 0.025 level. Hence, the omission rate was lower for the boys than for the girls. The t-test comparisons of the means from the subcategories indicated strong significant differences favouring the girls for all aspects except for multiple-choice questions (*MCQ*) and algebra items (*Algebra*). However, the effect sizes ranging between 0.18 and 0.35 for the significant categories indicated that the gender differences were small in magnitude in relation to the sample size.

Attitudes towards mathematics

To better comprehend the nature of mathematics achievement, this study extended investigation into the students' mathematics attitudes. Two-tail t-tests were used to locate significant differences between boys and girls. The summary statistics and t-values of the mathematics attitudes scores of the 9 subscales are presented in Table 2. Generally, the means of the female sample were higher than that of the male sample. Higher values indicated a more positive attitude towards the learning and doing of mathematics.

Insert Table 2 here

Results from Table 2 suggested that the GEP girls had more positive mathematics attitudes (*Maths Attitude*) than the boys. This was statistically significant at t-value = 4.27, $p < 0.001$. The effect size (0.45) of the differences was medium. t-test comparisons revealed that the female students obtained significantly higher mean score on attitude towards success in mathematics (*Fear of Success*). They also obtained a higher mean score on *Male Domain*. In fact, the differences were large at effect size of 1.10 for both the subscales of

Fear of Success and *Male Domain*. In addition, the girls were more inclined than the boys to perceive mathematics as being useful in their future career (*Usefulness*). The girls also had higher scores on the subscales of *Teacher* and *Effectance Motivation*. Their respective effect sizes are 0.36 and 0.40 respectively.

The negative t-value in *Anxiety* indicated that the boys scored higher than the girls. Although, the boys' anxiety level for mathematics was lower than the girls, the difference was not statistically significant. No significant gender differences were found in the rest of the subscales (*Anxiety, Confidence, Mother, Father*). 5 out of the 9 subscales exhibited gender differences favouring the girls.

Mathematics Attribution

The study used the attributional theory to further explain the mathematics performance of the GEP students. Table 3 contains information, by gender, on the sample sizes, means and variance of the responses to each of the subscales. Two-tail t-tests were performed on mean scores received by females and males on each of the 8 subscales of the MAS to determine if sex differences in attribution patterns exist.

Insert Table 3 here

Inspection of the results of the t-tests showed no gender differences except on the subscales, *Success_Ability*, *Success_Effort* and *Failure_Task*. On *Success_Ability*, the female mean was higher and on *Success_Effort*, the male mean was higher. The effect size for the *Success_Effort* subscale pointed towards medium gender differences. These results indicated that females attributed their success experiences in mathematics to their ability whereas males attributed their success to their effort and to their environment.

On the *Failure_Task* subscale, the mean of males was higher than that of females'. When failure experiences occurred in mathematics, males believed that failure was caused by the difficulty of the task. The effect size for *Failure_Task subscale* was not substantial (0.37). The present study found significant differences between females and males on 3 of the 8 MAS subscales.

Attitudes and Attribution Variables as significant predictors of SAT-M scores.

Factors to explain gender differences of the samples were explored. A general linear multiple regression model was used to examine the extent to which attitude and attribution subscales were predictive of achievement in SAT-M. The independent variables were the subscales: mathematics attitudes (*Confidence*, *Mother*, *Father*, *Teacher*, *Usefulness*, *Anxiety*, *Male Domain*, *Fear of Success* and *Effectance Motivation*) and attribution (*Failure_Ability*, *Failure_Environment*, *Failure_Task*, *Failure_Effort*, *Success_Ability*, *Success_Environment*, *Success_Task*, *Success_Effort*). The results presented in Tables 4 and 5 show that attitude (and their interactions with gender) and attribution (and their interactions with gender) variables were able to account for 16% and 6% respectively of the variations in SAT-M scores.

Insert Tables 4 and 5 here

A linear regression analysis was carried out separately between the dependent variable, SAT-M and each of the affective variables in attitude and attribution. The male and female slopes indicated the relationship between the dependent and independent variables. Tables 6 and 7 summarize the results of the separate linear regression analyses of mathematics achievement done for the female and male samples.

Insert Tables 6 and 7 here

Significant predictors were identified. *Confidence* ($R^2 = 0.0895$, $p < 0.0001$) and *Effectance* ($R^2 = 0.0930$, $p < 0.0001$) were the stronger predictors of SAT-M scores, each by itself was able to contribute about 9% to the total variance. In contrast, none of the attribution subscales was useful in explaining SAT-M performance. Individual subscales accounted for less than ½% of the variance in SAT-M scores. Among the girls, confidence in one's mathematical capacity (*Confidence*), level of mathematics anxiety (*Anxiety*) and their intrinsic motivation towards learning mathematics (*Effectance*) were significant predictors of the independent variable, SAT-M scores. For the male sample, the significant predictors included all the attitude subscales except *Father*, *Mother* and *Male_Domain*. Among the attribution subscales, *Success_Task* was the only significant predictor ($p < 0.05$) of boys' SAT-M achievement.

DISCUSSION

Results on the SAT-M test showed patterns of gender differences favouring the girls. In the MCQ section of the SAT-M there were no gender differences. The Singapore school system prepares its students in handling multiple-choice questions from the onset of elementary school; training could have evened out differences in performance between boys and girls. On the other hand, the boys were more willing to risk and guess on difficult items as indicated by the lower mean of the number of omitted items which is consistent with the findings from most gender stduies.

Generally, it is held that girls could only excel in items that contained materials taught by the teacher. This hypothesis does not hold in this study. The section containing quantitative comparison items have a format that is not commonly used in the classroom. Kimball (1989) hypothesised that boys might have an edge over the girls in nonroutine items. This study indicated that girls were better than the boys in quantitative comparisons. As students are generally not exposed to such items formats, doing well in them would represent a significantly high level of mathematics reasoning ability among the girls.

In terms of attitudes, significant gender differences were found in the following: teacher's attitudes towards the learning of mathematics, level of intrinsic motivation in the learning of mathematics, perception of mathematics as a Male Domain and the perception of possible effects of mathematics successes on appropriate sex role development. Research work (Wolleat, Pedro, Becker & Fennema, 1980; Stipek & Weisz, 1981) had shown that generally females' poor mathematics performance was linked to their learned helplessness. The 3 differences were in the reverse direction predicted from general attribution theory. The GEP males, when compared to their female counterparts, exhibited more of the learned helplessness pattern in their attribution of success and failure in mathematics. They used effort (unstable) to explain their success more strongly than females and pointed to ability (stable) to explained their successes less strongly than females. When explaining mathematics failure, males invoked the attribution of task difficulty (stable) more strongly than did females.

Attitude variables such as levels of anxiety, confidence and intrinsic motivation for the learning and doing of mathematics were significant predictors of SAT-M scores for both girls and boys. Teacher's attitudes towards mathematics learning and mathematics usefulness were effective in accounting for the remaining SAT-M variations among only the boys. None of the attribution behaviours was able to explain SAT-M performance among the GEP students.

A small subset of the attitude variables was useful in accounting for mathematics achievement variations. In addition, the relationships between these variables and mathematics achievement differed between males and females.

Implications of the Study

There are 3 implications for mathematics teachers and programme administrators involved in the education of the gifted.

Firstly, the study noted that the gender differences in mathematics achievement common in the general population (Kaur, 1987; Tan, 1990) were not evident among the gifted. This indicates that special intervention programme for females could contribute to higher mathematics achievement.

Secondly, a strong relationship between mathematics achievement and confidence in one's mathematics ability existed among the gifted girls. An important implication is that efforts should be maintained to raise the females' self-concepts in the learning and doing of mathematics. Teachers should provide a safe learning environment conducive to successful experiences in mathematics. Among the boys, various attitudes towards learning mathematics in an interesting and fun way were positively correlated to high mathematics achievement. Hence, a challenging mathematics programme is essential to the nurturing of mathematics potential among the boys.

The study has shown that SAT-M score was a function of attitudes and attribution styles. Therefore even among able students, maintaining a positive attitude to the learning and doing of mathematics is essential if their potential for high academic achievement is to actualise.

Finally, there is the question of whether the finding of this study on gifted students could be applicable to other talented students who are not participants in the GEP.

Suggestions for Further Research

Findings and implications of the study need to be weighed in view of its limitations. Firstly, the data and results referred only to gifted students participating in the Singapore's Gifted Education Programme and not to other gifted students who are in the regular curriculum.

Secondly the GEP is housed in the country's premier schools. There is the possibility of an interaction of both programme and school setting effects on gender differences in mathematics achievement.

Thirdly, the large unexplained variance of SAT-M scores by the effect of attitudes and attribution variables indicate that mathematics achievement could be sensitive to the type of mathematics learning environment, the philosophy in mathematics education held by the teachers concerned, the learning styles adopted by students and the out-of-class mathematics experiences of students. It would be informative for future research to show that these variables may have an impact over a larger period of time.

The limited generalisation of the findings suggest certain areas for further research at 2 levels. At the micro level, studies with a representative sample of gifted students from the regular curriculum can be carried out to provide data for comparison with the GEP students. Of interest would be areas in gender differences patterns, mathematics attitudes and mathematics attribution behaviour.

In addition, since the crux of any gender study rests on the relative position between boys and girls, research should examine the achievement levels for girls and boys separately over a period of years . Such findings would reveal how mathematics performance has changed for each sex. This would allow comparison of achievement levels between girls and boys to become more exacting and thorough.

Of educational interest is the role of intervention programmes to raise females' mathematics achievement. Studies could identify key features of the GEP that prove to be effective in raising female achievement in mathematics. The success of such programmes could be investigated in relation to the school climate and organisation. More information is needed to separate programme benefits from school effects such as single-sex setting, staff morale and school ethos.

On the macro level, future research should investigate how the curricula, pedagogical techniques and cultural factors interact with gender in impacting quantitative performance. Such studies could include comparison between gifted programmes across countries.

The published research on cognitive gender differences has focused on the pre-adolescent and adolescent years. Yet, abilities change over the adult years. Feingold (1988) observed that non-verbal and spatial abilities start to decline after a certain age. Participants after completing the GEP should be 'tracked' into adult lives so that research work could be carried out to determine whether developmental patterns continue to interact with gender to influence mathematics performance in adulthood.

Table 1 **Summary Statistics of the Raw Scores from SAT-M and t-tests between Females and Males**

	Females (n=142)		Males (n=220)		Effect Size	t-value
	Mean	SD	Mean	SD		
SAT	50.26	0.47	48.16	9.65	0.261	3.54***
MCQ	33.41	3.25	32.54	5.99	0.171	1.79
Quan	16.85	2.01	15.62	4.16	0.354	3.77***
Algebra	14.84	2.06	14.47	3.58	0.120	1.48
Arithmetic	13.65	1.19	12.91	2.64	0.338	3.84***
Geometry	14.57	1.37	13.82	2.48	0.355	3.94***
Miscellaneous	6.90	1.31	6.61	1.84	0.176	1.97*
Figure	16.52	1.82	15.75	3.19	0.281	3.21***
Omissions	1.26	2.22	0.94	2.82	0.123	1.200

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 2 **Summary Statistics and t-tests of Fennema-Sherman Mathematics Attitude Subscales Scores between Females and Males**

Subscale	Females (n=141)		Males (n=210)		Effect Size	t-value
	Mean	SD	Mean	SD		
Maths Attitude	405.28	45.05	382.15	55.97	0.446	4.27***
Confidence	42.86	8.97	42.37	9.86	0.052	0.48
Mother	44.36	7.64	42.88	7.15	0.201	1.82
Father	44.77	7.95	43.28	7.86	0.189	1.73
Teacher	43.06	6.57	40.62	6.85	0.362	3.35***
Usefulness	45.20	7.49	42.94	9.44	0.260	2.49*
Anxiety	38.45	10.00	39.13	9.26	-0.071	-0.64
Male Domain	50.76	6.15	42.13	9.33	1.052	10.45***
Fear of Success	50.94	5.78	42.13	9.33	1.089	10.91***
Effectance Motivation	44.90	8.09	41.42	8.97	0.403	3.78***

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 3 **Summary Statistics and t-test on Mathematics Attribution Scores between Females and Males**

Attribution of Success

Subscales	Female (n=144) Mean	Female (n=144) SD	Male (n=224) Mean	Male (n=224) SD	Effect Size	t-value
Ability	12.81	3.22	11.87	3.62	0.271	2.62**
Effort	10.46	3.15	11.84	3.46	-0.413	-4.02***
Task	9.19	2.02	9.37	2.48	-0.078	-0.73
Environment	10.12	2.33	10.76	2.59	-0.257	-2.47*

Attribution of Failure

Subscales	Female (n=144) Mean	Female (n=144) SD	Male (n=224) Mean	Male (n=224) SD	Effect Size	t-value
Ability	11.89	3.30	12.59	3.38	-0.209	-1.95
Effort	10.06	2.73	10.51	3.16	-0.150	-1.41
Task	10.65	2.54	11.69	2.94	-0.373	-3.60**
Environment	13.65	2.67	13.66	2.80	-0.004	-0.01

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4 **Summary of the General Linear Regression Analyses on SAT-M Scores and Attitude Variables**

Dependent Variable: SAT-M Scores

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	19	54.31	2.70	3.22	0.0001
Error	309	274.69	0.89		
Corrected Total	328	329.00			

R-Square	C.V.	Root MSE	SAT-M Mean
0.1651	-9999.99	1.00	-.0000

Table 5 **Summary of the General Linear Regression Analyses on SAT-M Scores and Attribution Variables**

Dependent Variable: SAT-M Scores

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	17	19.90	1.17	1.18	0.2809
Error	312	310.10	0.99		
Corrected Total	329	330.00			

R-Square	C.V.	Root MSE	SAT-M Mean
0.0603	-9999.99	1.00	-.0000

Table 6 **Summary of the separate Linear Regression Analyses on SAT-M Scores as the Dependent Variable**

Dependent Variable = SAT-M scores

N = 340 Total Sum of Squares = 340

Attitude Variables	R^2 (Prob < F)	Female Slope	Male Slope	Difference/Slope
Father	0.0009 (0.0805)	-0.038	0.176*	-0.241
Mother	0.0070 (0.1269)	-0.008	0.241	-0.148
Anxiety	0.0516 (0.0001)	0.218**	0.244***	-0.026
Confidence	0.0895 (0.0001)	0.252**	0.322***	-0.071
Teacher	0.0546 (0.0001)	0.163	0.259***	-0.096
Male Domain	0.0016 (0.4728)	-0.201	0.037	-0.238
Fear/Success	0.0554 (0.0001)	-0.009	0.289***	-0.298
Useful	0.0334 (0.0009)	0.081	0.213***	-0.132
Effectance	0.0930 (0.0001)	0.205*	0.341***	-0.136

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 7 **Summary of the separate Linear Regression Analyses on SAT-M Scores as the Dependent Variable**

Dependent Variable = SAT-M scores

N = 352 Total Sum of Squares = 340

Attribution Variables	R^2 (Prob<F)	Female Slope	Male Slope	Difference/Slope
Success				
Task	0.0046 (0.2212)	0.101	-0.134*	0.235*
Effort	0.0000 (0.9909)	0.127	-0.032	0.159
Environment	0.0045 (0.2264)	0.160	0.032	0.128
Ability	0.0040 (0.2535)	-0.148	-0.046	-0.103
Failure				
Task	0.0002 (0.8136)	0.054	0.031	0.024
Effort	0.0001 (0.8540)	0.048	0.012	0.036*
Environment	0.0000 (0.8566)	-0.021	-0.002	-0.019
Ability	0.0067 (0.1369)	0.142	0.060	0.081

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

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