Running Head: GENDER DIFFERENCES IN MATHEMATICS

# Gender Differences in Mathematical Abilities

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Several studies have found that gender differences exist in mathematics with boys typically performing better than girls from adolescence on (Alkhateeb, 2001). The general acceptance in the literature is that boys are generally better than girls at mathematics from adolescence on. This is at approximately 13-19 years of age. Friedman (1989) did a meta-analysis of recent studies on sex differences in mathematical tasks and found that gender differences favoring girls disappears in early adolescence and this is when reliable gender differences favoring boys emerge and persist through high-school and college.

Gender differences in mathematics appear to be more complex than some might have assumed (Duffy, Gunther, & Walters, 1997). In the discussion that follows, evidence for gender differences is considered as well as theories explaining these differences, in an attempt to determine whether one model explains the gender differences in mathematics better than the others.

## Evidence of Gender Differences in Mathematics

The superiority of males' mathematical skills has been a controversial issue for decades among social scientists. Strong evidence for a male advantage comes from Leahey & Guang's (2001) study on mathematical differences in mathematical trajectories. The research demonstrated that a slight gender difference in favor of males in the eighth grade exists and it increases throughout the high school years. In eighth grade, male students scored 0.5 points higher than females on average, but by twelfth grade, this difference increased to 1.32 (Leahey & Guang, 2001).

Lamb (1997) also found evidence of a male advantage by identifying some of the dimensions underlying gender differences in mathematics participation. A survey of ten to twelfth grades at four different high schools demonstrated that girls are less likely than boys to enter mainstream mathematics in senior high school because of differences in responses to mathematics and in assessments of abilities in mathematics. The separation of senior school mathematics into academic and non-academic subjects was more efficient for males than for females because in the junior years of high school males develop more positive views of mathematics and of themselves as mathematics learners leading to them more often selecting the university-preferred options.

Fan and Chen (1997) found evidence of a male advantage in mathematics using data from the National Education Longitudinal Study of 1988. National samples were used in order to investigate gender differences in mathematics achievement. Gender differences were not found when total-group means were compared, but noteworthy gender differences emerged when the high end of math score distributions was examined. These differences increased from the eighth grade to the twelfth grade and were more extreme score ranges. The observed gender differences for students at the high end of the math score distributions are of importance because these students are very likely to consider pursuing careers in mathematics and science. Gender differences at the high end of the math score distribution are likely to be one of the reasons for the gender imbalance in the flow of new students into mathematics and science careers (Fan & Chen, 1997).

Carr, Jessup, & Fuller (1999) demonstrated gender differences in strategy use in first-grade mathematics. A strategy was categorized as retrieval if the student described pulling the information from memory or said that the information just "popped" into his or her head and a strategy was categorized as overt if the student used counters or counted on their fingers. Differences in strategy use do exist as early as the first grade; boys use retrieval more often than girls do and girls use over strategies more often than boys do.

Beller & Gafni (2002) investigated differential performance of boys and girls on open-ended and multiple-choice items on the 1988 and 1991 International Assessment of Educational Progress (IAEP) mathematics test. In the 1988 mathematics assessment, a representative sample of 13-year-olds was assessed and in the 1991 mathematics assessment, there was a sample of 9-and 13-year olds. An analysis of both assessments indicated that males generally performed better than females in mathematics (Beller & Gafni, 2000). The 1988 assessment found that gender effects were larger on multiple-choice items, however, the 1991 assessment found the opposite results; gender effects were larger on open-ended items than on multiple-choice items. Correlations between item gender effect size and item difficulty suggested that as the items increased in difficulty, the males performed better relative to the females (Beller & Gafni, 2000).

Gender differences have also been found between 5$^{th}$-grade boys and girls at approximately 11-12 years of age. At fifth grade a gender difference of students computational arithmetic performance can be observed. Hopkins & Lisi (1997) examined student gender and teaching methods as sources of variability in students' computational arithmetic performance. Two instructional modes were used; didactic teaching approach and constructivist teaching approach. The didactic teaching method emphasized the presentation of rules and computational formulas and the constructivist teaching method consisted of suggesting ways to organize a task. The results revealed that didactic instruction leads to increased levels of success for females being taught algorithms in the fifth grade (Hopkins & Lisi, 1997). Didactic instruction does not disadvantage the males, rather, it boosts computational performance in the females. This suggests that instructional methods may reduce the computational advantage of females when mathematics is taught by a teacher didactically.

Ramos (1996) studied the role of attribution and significant others in gender differences in mathematics and found a significant difference between the percentage of females and males who believed that they are good at mathematics. Ninety-seven college students completed a questionnaire that measured attribution in mathematics and the role played by parents, teachers, and peers. The aim of the study was to determine whether a significantly greater percentage of males viewed themselves as being good at mathematics. A significant difference was found for the percentage of females and males who believed they were good in mathematics. Forty-five percent of females believed they were good in mathematics compared to sixty-seven percent of the males (Ramos, 1996).

Models of Gender Differences in Mathematics

Models of the gender differences in mathematics have been described in the literature and vary extensively. Three models attempt to explain the gender differences in mathematics; biological, social, and psychobiosocial models. Differences may be biologically based, or derived from an individual's experience, or a combination of the

Two.

Biological Model

The biologically based model attempts to explain gender-related differences in mathematics through genetic and/or hormonal variables. In other words, the differences are built-in and unchangeable. Gender differences were initially attributed to biological causes.

Geschwind (as cited in Callas, Dennis, 1993), for instance, proposed that male superiority in mathematical skills was due to exposure to more testosterone while in utero. Presumably, this lead to changes in brain function or anatomy. This approach does not deny the effects of gender differences in socialization on mathematics performance, but would argue that inherent biological differences underlie gender differences in mathematics. This approach has raised the possibility that gender differences in mathematics may not be changeable. On the other hand, Callas (1993) found that gender differences in favor of males are minimal and decrease over time, which challenges the biological theory. If gender differences decrease over time, than this may signify that they cannot be inherent, and therefore have a good chance of being connected to different male and female experiences in the environment. There is little evidence to support the pure biological model, although if there is a dramatic change at puberty, regardless of any experience, then this would suggest that it is not due to cultural differences.

Social Model

In contrast to the biologically based model of gender differences in mathematics is a social model. This model says that people expect boys to be better at mathematics and these expectations actually produce the expected results. If you treat the boys that way, then the boys develop more confidence in mathematics.

An explanation for the male advantage for mathematics may be found in effects of teacher beliefs. Li (1999) reviewed gender issues and teachers' beliefs regarding mathematics education and found that teachers had higher expectations for boys, with respect to math ability. Teachers tend to stereotype mathematics as a male domain; this has been reflected in teachers' tendency to overrate male students' mathematics capabilities, and have more positive attitudes about male students (Li, 1999). In other words, male students seem to get more attention from the teacher than females do in mathematics class. Both male and female teachers tend to interact more often with male students (Li, 1999). Teachers need to recognize and understand that preconceived attitudes and expectations about boys and girls in mathematics are likely to have an effect on students. Teachers can be beneficial in boosting the confidence of girls in mathematics classes and supplying role models. This model predicts that different experiences are the main source of the gender differences in mathematics. The majority of evidence supports the social model of influences on gender differences in mathematics.

Psychobiosocial Model

Halpern's (as cited in Gallagher, Ann, 1998) psychobiosocial model of cognitive development argues that societal and biological factors interact systematically to create differences in girls' and boys' cognitive abilities. In other words, it involves the expectancy of girls and boys in mathematics along with genetics. This is the most recently introduced model to explain the gender differences in mathematics. This model has been used to trace how differences in socialization patterns may contribute to cognitive processing differences, which then may lead to performance differences on tests (Gallagher, Ann, 1998). In other words, small genetic predispositions influence early experience and experience influences development, which in turn influences future experiences and future development (Gallagher, 1998). There is very little evidence to support the psychobiosocial model of influences on gender differences in mathematics.

Conclusion

There is a general agreement that gender differences occur in mathematics (Alkhateeb, 2001). Gender differences do exist in mathematics, although the differences are now smaller than in the past. Findings of Alkhateeb's (2001) study on gender differences in mathematics achievement among high school students in the United Arab Empires, 1991-2000 indicated a decline of gender difference in high school final mathematics achievement; more precisely, the gender gap on achievement test scores appears to be closing. The gender differences in mathematics have somewhat diminished, however they still exist and still inhibit females from pursuing mathematics futures.

Much more evidence exists in favor of the social influences on gender differences, opposed to biological, or a combination of influences. Findings from Alkhateeb's (2001) study support the claim that the differences in mathematics achievement is due to societal influences, not genetic. The biological model does not adequately explain all the gender differences found in mathematics and it is apparent that social factors, such as experience, may provide another cause for the observed gender differences in mathematics. Callas's (1993) study may be of an advantage in ruling out biological factors because it provides evidence that gender differences are small and have decreased over the years. There is a great deal that still needs to be known in the way of gender differences in mathematics. The review of literature identifies a lack of investigation into the different models that attempt to explain gender-related differences in mathematics.

Some needed investigation might include continuing research into the different models that attempt to explain gender-related differences in mathematics. Also, more research is needed on the actual effects of teacher gender and teachers' perceptions of boys and girls in mathematics.

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## ABSTRACT

Do mathematical abilities appear to develop gradually in response to society's expectations, or do they develop relatively suddenly at puberty? Girls and boys from fourth grade, eighth grade and twelfth grade completed a questionnaire regarding attitudes toward mathematics. Three measures of attitude were used; confidence in mathematics, usefulness of mathematics, and mathematics as a "girls domain." A statistically significant gender difference was found between girls' and boys' attitudes toward mathematics overall. The difference was almost entirely due to the measure of mathematics as a "girls domain." A statistically significant grade difference in confidence of ability to succeed at mathematics was found; confidence increased from grade four to grade eight, then decreased again in grade twelve. A downward trend for girls was found in two of the three dimensions of attitude measured, consistent with previous research. Over grade levels, girls show an increased negativity toward mathematics as a "girl domain." The data suggest that there are multiple dimensions of attitude. More research is needed on the sub-dimensions of attitude, rather than attitude as a global whole.

Gender Differences in Mathematical Abilities

Gender differences have been found as early as the first grade. Carr, Jessup, & Fuller (1999) examined gender differences in strategy use in first-grade mathematics. A strategy was categorized as retrieval if the student described pulling the information from memory or said that the information just "popped" into his or her head and a strategy was categorized as overt if the student used counters. The results showed that boys use retrieval more often than girls do and girls use overt strategies more often than boys do.

Gender differences have also been found between fifth grade boys and girls at approximately 11-12 years of age. At fifth grade a gender difference of students computational arithmetic performance can be observed. Hopkins & Lisi (1997) examined student gender and teaching methods as sources of variability in student's computational arithmetic performance. Two teaching methods used were; didactic and constructivist. The didactic teaching method emphasized the presentation of rules and computational formulas and the construcivist teaching method consisted of suggesting ways to organize a task. The didactic teaching method worked better with girls than with boys when being taught algorithms.

The general acceptance in the literature is that boys are generally better than girls at mathematics from adolescence on (Friedman, 1989). This is at approximately 13-19 years of age. Friedman (1989) did a meta-analysis of recent studies on sex differences in mathematical tasks and found gender differences in early adolescence. Reliable gender differences favoring boys emerge in adolescence and persist through high school and college.

Three models attempt to explain the gender differences in mathematics. The first model is the biological model and it attempts to explain gender-related differences in mathematics through genetic and/or hormonal variables. In other words, the differences are built-in and unchangeable. This approach has raised the possibility that gender differences in mathematics may not be changeable. On the other hand, Callas (1993) found that gender differences in favor of males are minimal and decrease over time, which challenges the biological theory. If gender differences decrease over time, then this may mean that they cannot be inherent, and therefore have a good chance of being related to different male and female experiences in the environment. There is little evidence to support the pure biological model, although if there is a dramatic change at puberty, regardless of experience, then this would suggest that it is not due to cultural differences.

The second model is the social model and it says that people expect boys to be better at mathematics and these expectations actually produce the expected result. Li (1999) reviewed gender issues and teachers' beliefs regarding mathematics education and found that teachers had higher expectations for boys, with respect to math ability.
The majority of evidence supports the social model of influences on gender differences in mathematics.

The third model is Halpern's (as cited in Gallagher, Ann, 1998) psychobiosocial model and it argues that societal and biological factors interact systematically to create differences in girls' and boys' cognitive abilities. In other words, it involves the expectancy of girls and boys in mathematics along with genetics. Gallagher (1998) found that small genetic predispositions influence early experience and early experience influences development, which then influences future experiences and later development. The psychobiosocial model is the most recently introduced model, but there is little evidence to support it.

The majority of evidence supports the social model of influences on gender differences in mathematics. I want to determine if a particular pattern emerges, one that fits the social model. Do mathematical abilities appear to develop gradually in response to society's expectations, or do they develop relatively suddenly at puberty? Is there only one dimension of attitude or is attitude multi-dimensional? I will look at sub-dimensions of girls' and boys' attitudes toward mathematics across grade levels in order to try to find a pattern across grade levels, one that fits the social model.

# Method

*Participants*

The participants consisted of 27 fourth graders (17 girls & 10 boys), 17 eighth graders (13 girls & 4 boys), 101 twelfth graders and OAC students (47 girls & 54 boys). The grade twelve students and OAC students were grouped together. There were a total of 145 participants in all; 77 girls and 68 boys. . A reward of a treat was offered by teachers to students in the fourth and eighth grades for returning the consent forms, but not to students in the twelfth/OAC grade.

Three local public elementary schools and two local public secondary schools were selected for the study. Average schools were selected, rather than schools with upper-class, or lower-class reputations in order to avoid any selection bias

*Procedure*

My procedure entailed a 16 statement questionnaire, similar to the Modified Fennema-Sherman Attitude Scales (Doepken, Lawsky, & Padwa, 1970). The responses on the questionnaire were on a 5 point scale, ranging from 1. Strongly agree to 5. Strongly disagree. There were an equal number of positively and negatively worded statements. Eight statements measured a positive attitude and the other eight statements measured a negative attitude. The sixteen statements were grouped according to four variables and they were; personal confidence about mathematics, usefulness of mathematics, mathematics is perceived as a "girls domain," and students' perception of teachers' expectations of boys and girls in mathematics. Four statements were grouped according to each variable. This was done in order to score the questionnaires.

Confidence referred to one's own belief in ability to succeed at mathematics. The higher the score was on confidence, the higher the belief to succeed in mathematics was. Usefulness referred to one's own belief of the purpose of mathematics. The higher a score was on usefulness, the higher the belief of the purpose of mathematics was. Mathematics as a "girl domain" referred to one's own belief of girls excelling at mathematics. The higher a score was on "girl domain", the higher the belief of girls excelling in mathematics was. And finally, students' belief of teachers' expectations of boys and girls in mathematics referred to one's own perception of teacher's attitudes. The higher the score on this variable, the higher the belief that teachers place different expectations on boys and girls in mathematics was.

The five principals were approached by the experimenter with a brief introduction of herself and the questionnaire. Also, each principal was given a package that contained the consent form and questionnaire in order for them to review it. After principal approval, the consent forms were distributed to students by their teachers. The grade 12 mathematics students were mostly over the age of 18, which meant that they could sign the consent form themselves, but the one's that were under 18 needed a parental or guardian signature. Almost all the students under the age of 18 brought their consent forms back, which means that there was no selection bias for the older students.

The questionnaire was presented by the experimenter to each class to the student that had returned their signed consent forms. First, the experimenter briefly introducing herself, then indicated to the students that the questionnaire was related to attitudes towards mathematics and stressed the fact that it was completely anonymous. Each student was given a plain white envelope with the questionnaire and upon its completion it was to be sealed and placed in a questionnaire box in which the experimenter provided. The treats were distributed to the grade four and eight students that had returned the signed consent form. The treats were distributed by the experimenter along with the questionnaire. The questionnaire required approximately ten minutes for its completion. When all questionnaires were completed and in the questionnaire box, the experimenter indicated to the students that the results would be available from their school principal or they could contact the experimenter directly for a copy of the results.

## Results

The forth dependent variable, students belief of teachers' expectations, was eliminated from the results, due to the fact that there was a mistake in wording of one of the questions which made the boys results impossible to interpret correctly. When all three measurements of attitudes towards mathematics were compared by gender, a gender difference between girls' and boys' beliefs of mathematics was found. By looking at figure I, you can see that girls had a better overall attitude about mathematics then the boys did. It is interesting to note that when all three measurements of attitude were separated the gender difference was found to be only due to mathematics as a "girl domain," not due to confidence or usefulness of mathematics (see figure II). By looking at figure II, you can see that girls had a higher belief of mathematics as a "girl domain" than the boys did, but boys and girls had similar beliefs of their confidence and usefulness of mathematics.

A significant grade difference in confidence of ability to succeed at mathematics was found, $F(2, 145) = 3.616$, $p = .029$. Figure III shows that grade 8 boys and girls both had the highest level of confidence in their ability to succeed at mathematics, when compared to grade 4 and 12 students. Confidence to succeed in mathematics increased from grade 4 to 8 then dropped back down again in grade 12. Also, it is interesting to note from figure III that boys and girls changed in the same way over grade levels, but this was not a statistically significant gender difference.

Grade 4 girls had a significantly higher belief of the usefulness of mathematics when compare to grade 4 boys, $F(2, 145) = 3.103$, $p = .048$. You can see in figure IV that grade 4 boys had a low belief of the usefulness of mathematics, then it increased in grade 8, then dropped back down in grade 12. The same downward trend existed here as existed in Figure III. There was a gradual decline in girls' beliefs of mathematics usefulness from grade 8 to 12.

Another significant gender difference was found between grade 4 boys' and girls' perceptions of teachers' expectations of boys and girls in mathematics, $F(1, 145) = 8.106$, $p = .005$. Figure V shows that girls had a significantly higher belief of mathematics as a "girls domain" than the boys did and also, a downward trend for girls existed from grade 4 to 12, girls found mathematics to be less of a "girls domain" over grade levels.

## Discussion

The present data show that students in mid-school favor attitudes towards girls doing math, but this declines by grade 12. Also, a downward trend exists for girls in two of the three components of attitude, which is consistent with the literature. Different results may have been received if there was more participants in each grade level, especially at the grade 4 and 8 levels. The low participation from grade 4 and 8 students a result of the small return rate of consent forms and I am not positive that the grade 4 and 8 teachers indicated to their students that they would receive a reward of a treat for returning their consent forms. Further research on how these declines occur and why they occur are needed. This will give us an even greater insight into girls' and boys' attitudes toward mathematics.

To conclude, the pattern of mathematical abilities does not occur in response to society's expectations or suddenly at puberty. This data show some evidence for the social model and also support the growing trend that the gender gap is closing in mathematics. The gender gap on achievement test scores appears to be closing (Alkhateeb, 2001). Further research should focus on the models that attempt to explain the gender differences in mathematics.

Many dimensions of mathematics attitude exist and by breaking it down, significant differences can be found. I looked at three dimensions of attitude and found that the dimensions of attitude were not all the same. Two of the dimensions showed a trend in the downward direction. More research also needs to be done on the sub-dimensions of attitude, rather than attitude as a global whole.

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# Figure Captions

*Figure I.* Total mean score as a function of gender and overall attitude.

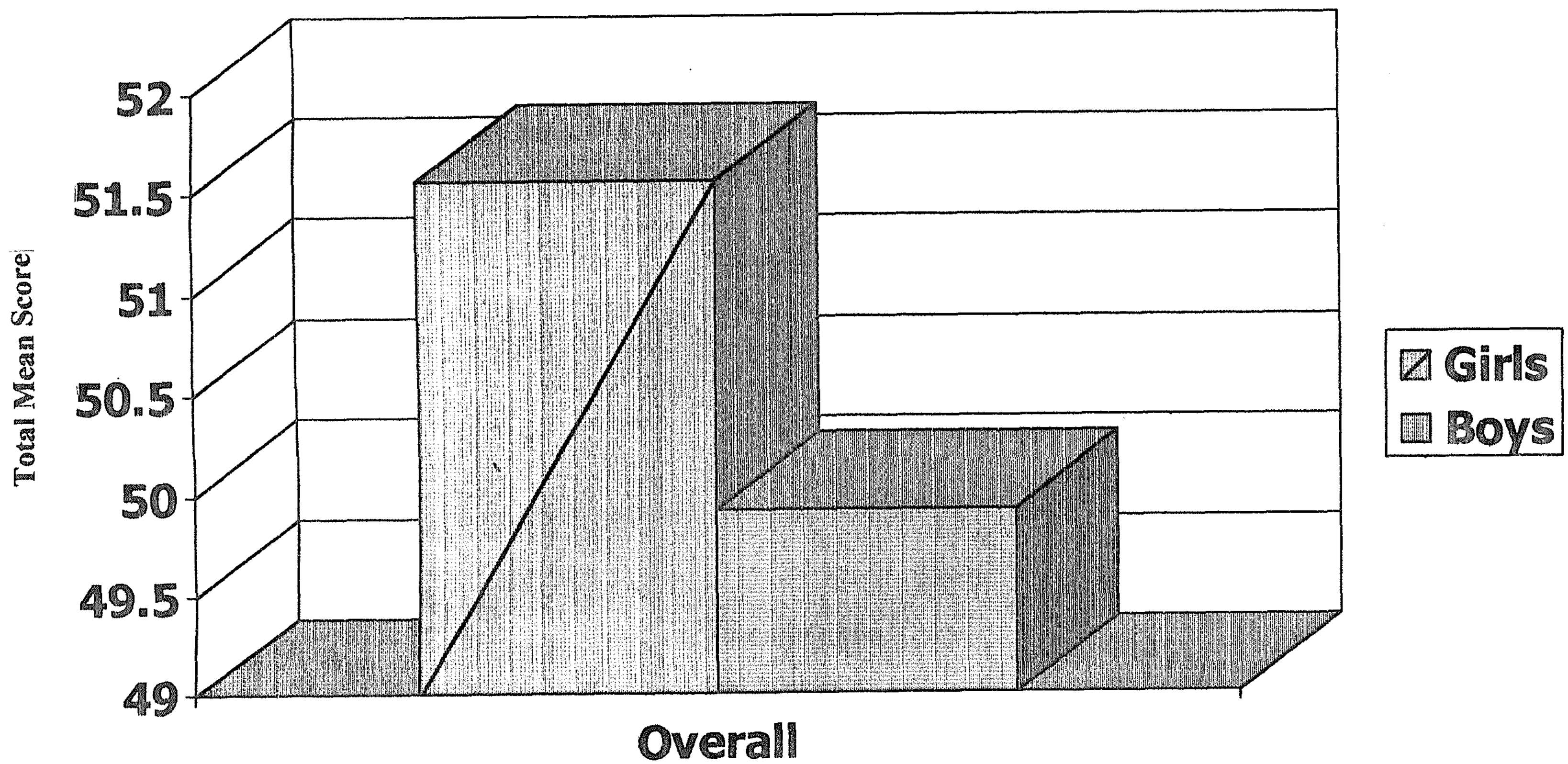
*Figure II.* Mean score as a function of gender and three different measures of attitude.

*Figure III.* Mean score for confidence as a function of gender and grade.

*Figure IV.* Mean score for usefulness as a function of gender and grade

*Figure V.* Mean score for girls domain as a function of gender and grade.

Figure I




All Measures of Attitude Combined

Figure II

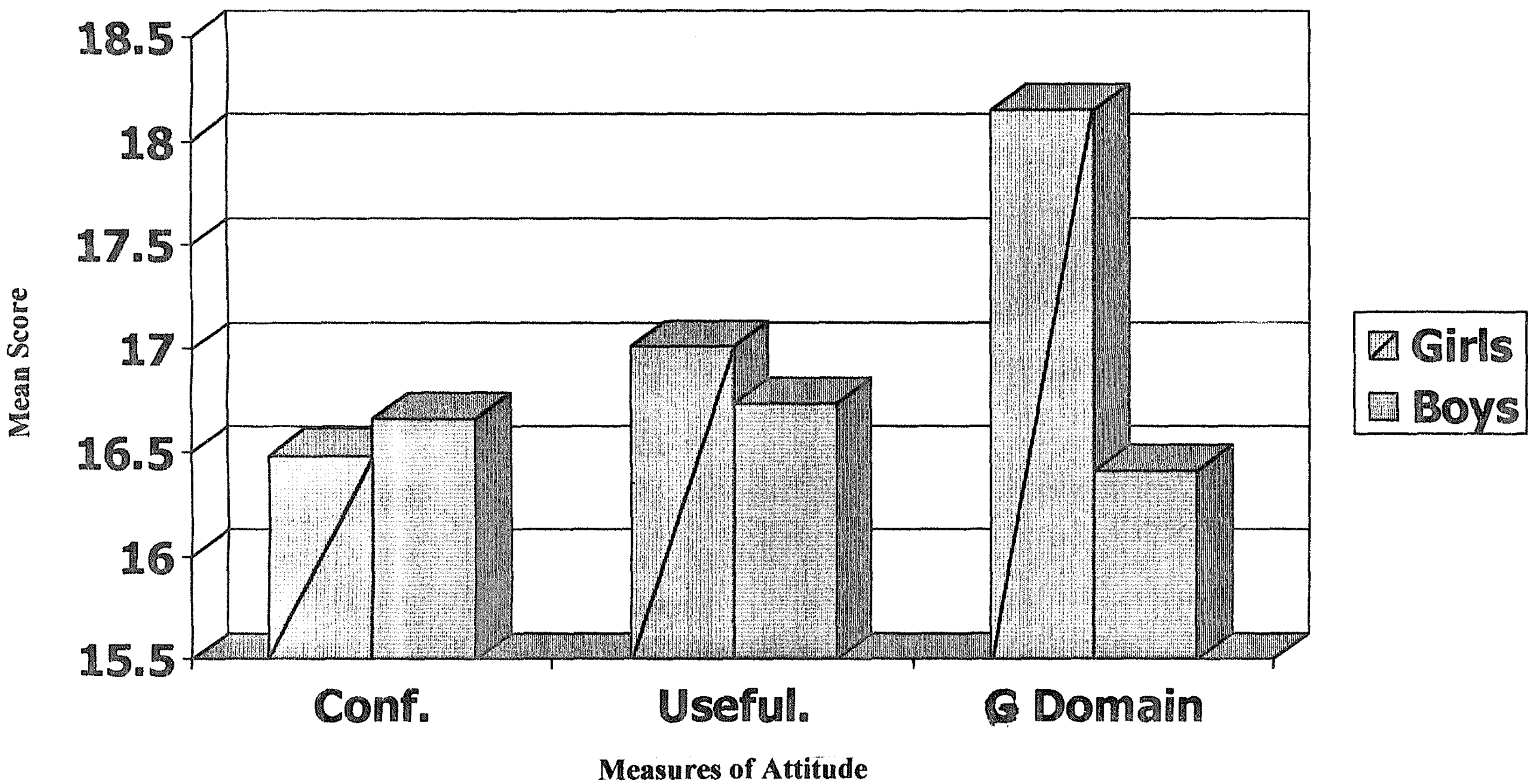
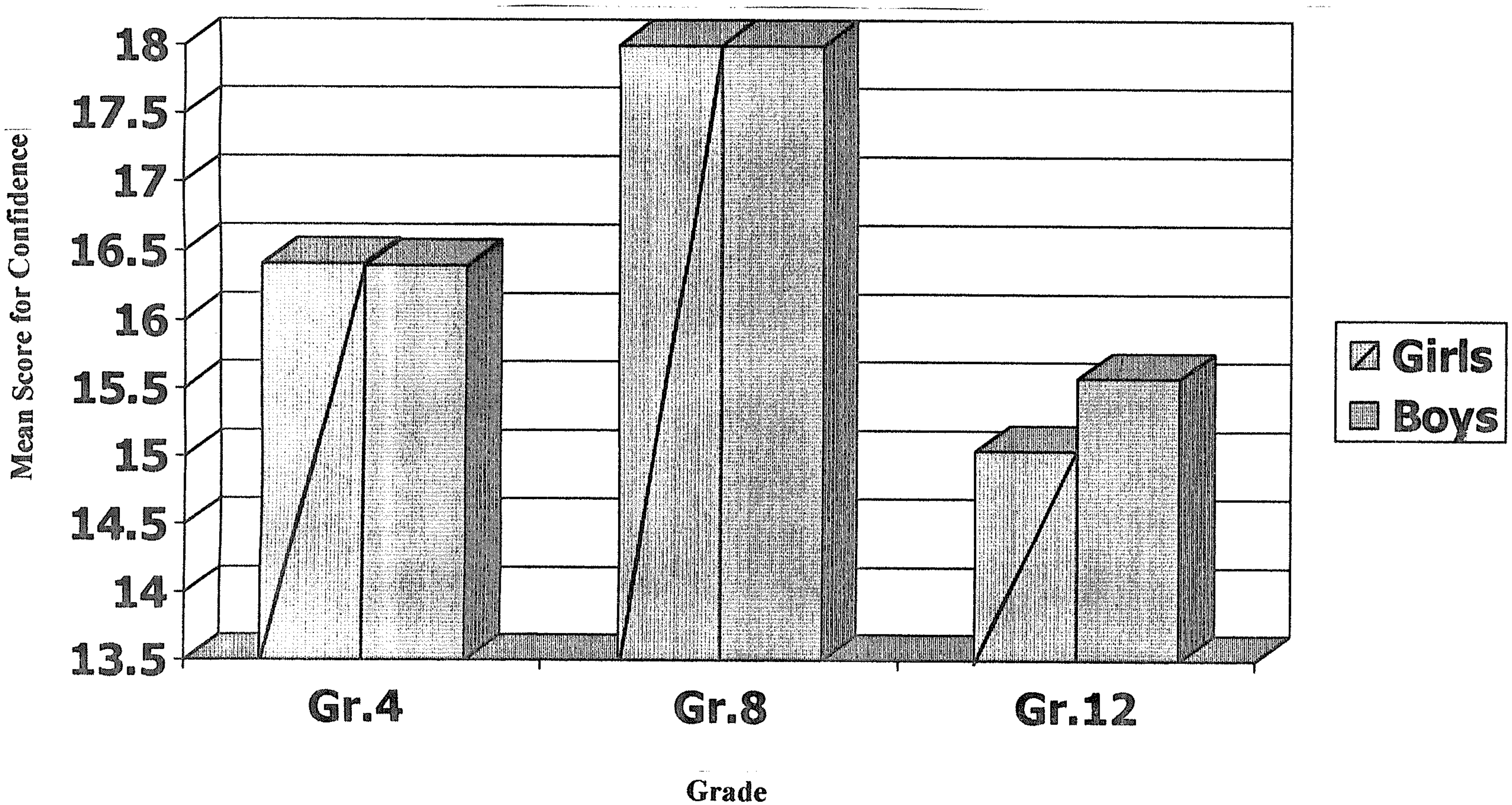
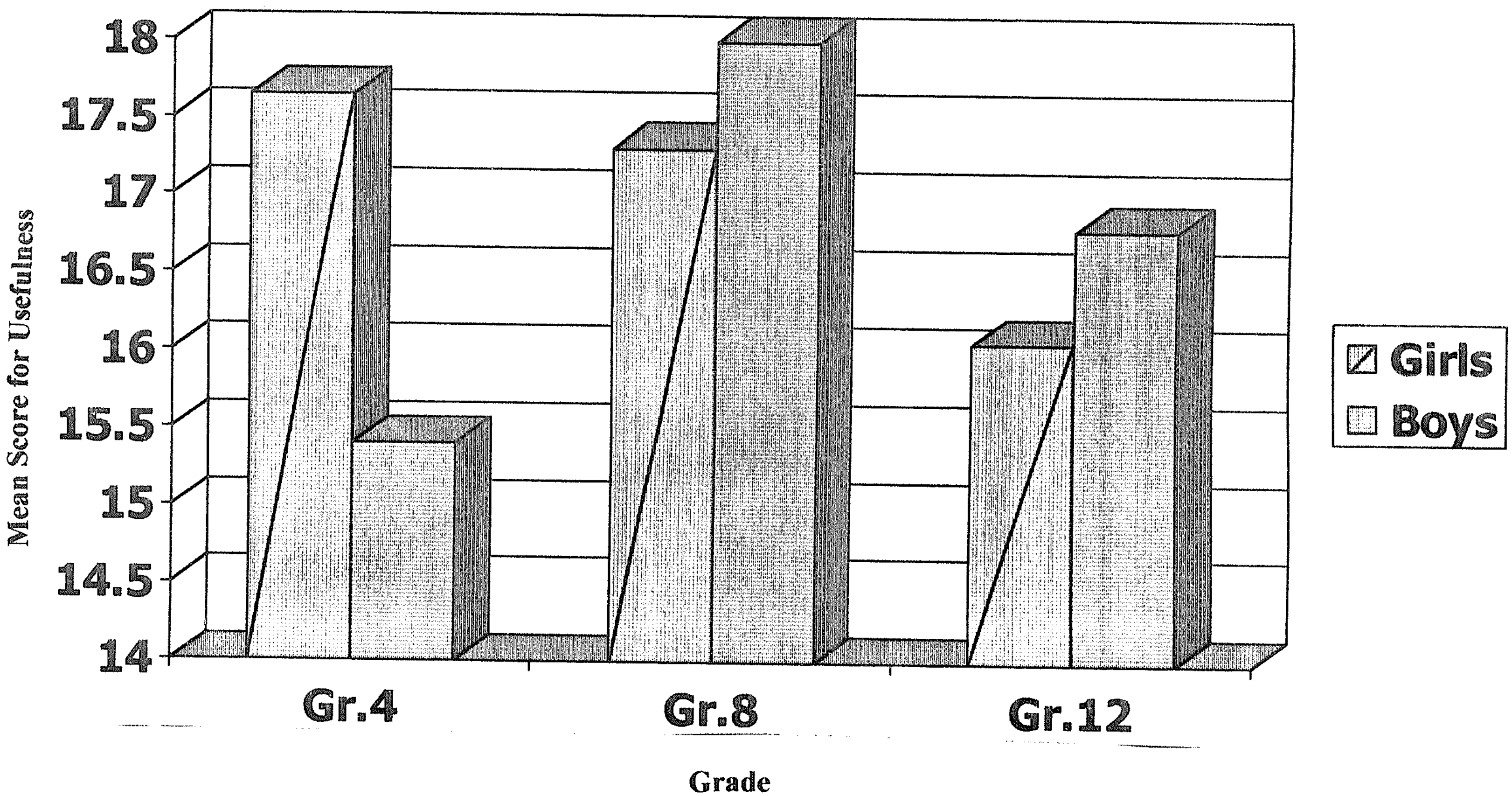

18.5
18
17.5
17
16.5
16
15.5
Mean Score
Girls
Boys
Conf.
Useful.
G Domain
Measures of Attitude

Figure III



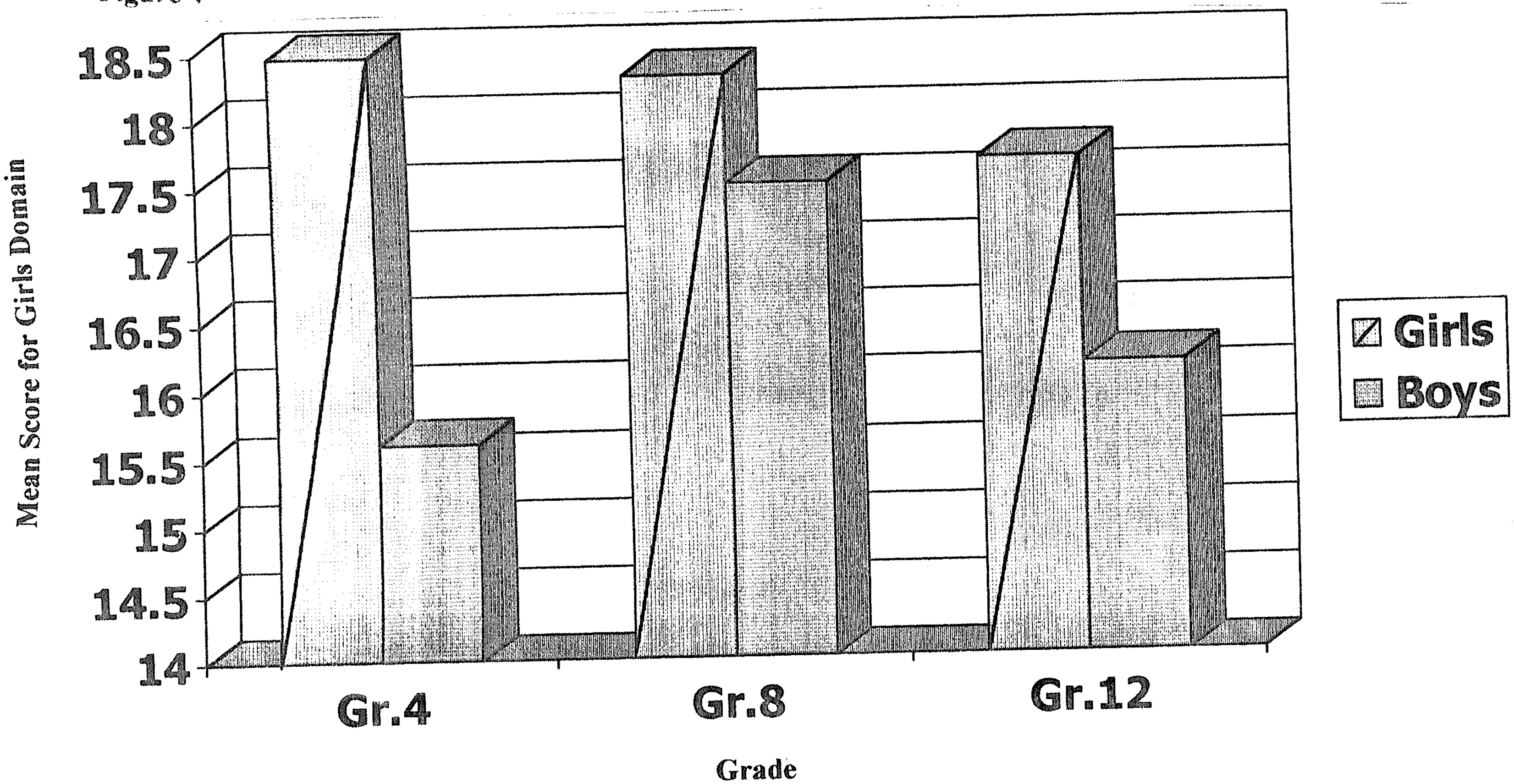
18
17.5
17
16.5
16
15.5
15
14.5
14
13.5
Mean Score for Confidence
Gr.4
Gr.8
Gr.12
Grade
Girls
Boys

**Figure IV**



18
17.5
17
16.5
16
15.5
15
14.5
14
Mean Score for Usefulness
Gr.4
Gr.8
Gr.12
Grade
Girls
Boys

Figure V


18.5
18
17.5
17
16.5
16
15.5
15
14.5
14
Mean Score for Girls Domain
Gr.4
Gr.8
Gr.12
Grade
Girls
Boys