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Gender, autonomous learning behavior and confidence in learning math: Predicting math performance on routine and non-routine word problems and standardized tests

Caporrimo, Rosaria, Ph.D.

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U·M·I
300 N. Zeeb Rd.
Ann Arbor, MI 48106

GENDER, AUTONOMOUS LEARNING BEHAVIOR AND CONFIDENCE IN LEARNING MATH: PREDICTING MATH PERFORMANCE ON ROUTINE AND NON-ROUTINE WORD PROBLEMS AND STANDARDIZED TESTS

by

ROSARIA CAPORRIMO

A dissertation submitted to the Graduate Faculty in Educational Psychology in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York

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Date

Chair of Examining Committee

Date

Executive Officer

Dr. Sue Rosenberg Zalk

Dr. Carol Kehr Tittle

Dr. Alan Gross

Supervisory Committee

The City University of New York

Abstract

GENDER, AUTONOMOUS LEARNING BEHAVIOR AND CONFIDENCE IN LEARNING MATH:
PREDICTING MATH PERFORMANCE ON ROUTINE AND NON-ROUTINE WORD PROBLEMS AND STANDARDIZED TESTS

by

Rosaria Caporrimo

Advisor: Professor Sue Rosenberg Zalk

This research attempted to design a measure of autonomous learning behavior (ALB) and used scores on this instrument, along with confidence in learning math, and gender to predict scores on a routine and non-routine word problem task and a standardized math test. The study was conducted in two phases - instrument development and student data collection - and was the first to draw on math teachers' working knowledge to define ALB. Two instruments were developed: a Student ALB Self-Report Questionnaire, and a routine and non-routine word problem-solving task. The Student ALB Self-Report measure was presented in a manner that allowed students to indicate what strategies they used when solving the non-routine word problem presented prior to the questionnaire. Items also tapped strategies and behaviors possibly used by students in the math classroom. The problem-solving task consisted of six routine and six non-routine word problems.

One hundred twenty-two students - 70 females and 52 males - responded to the Student ALB Self-Report

Questionnaire, a Confidence in Learning Math Scale (Fennema & Sherman, 1976), and solved the 12 word problems. Students' scores on the math section of the Iowa Test of Basic Skills were also obtained.

Multiple regression analyses were used to determine which variables were predictors of the dependent variables routine and non-routine word problem score, and standardized math test score. Results indicated that none of the variables successfully predicted non-routine word problem score. In the prediction of routine problem score, ALB alone was not a significant predictor, however, the addition the Gender*Confidence interaction term into the equation resulted in a significant prediction. For the standardized test score, ALB alone was a significant predictor, and the addition of the Gender*Confidence interaction term resulted in a significant increase in this prediction. In both significant predictions, though, the variance accounted for was only 9%. When considering ALB, confidence related to routine problem scores and standardized test scores differently for males and females. For males, higher achievement scores occurred in conjunction with higher confidence scores. For females, confidence was unrelated to the standardized math test score and inversely related to routine problem score. Suggestions for further research are discussed.

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Dedication

This dissertation is dedicated to the treasured memory of my father, John Caporrimo. He referred to me as "my daughter, the doctor," from my first semester at the Graduate Center. His pride in me and the memory of his love give me strength and courage; memories of his smile and laughter are visions I treasure.....

and

To the memory of my sister, Antonina C. Castiglione. As children we shared giggles, fights and secrets. As an adult, I've missed her sparkling blue eyes.....her spirit and memory are alive in me always.....

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I. INTRODUCTION

While the past decade has witnessed a dramatic change in the types of occupations pursued by women, there is a continuing dearth of women entering the traditionally male-dominated careers in which the study of advanced mathematics is an important prerequisite. A focus on career education at the high school level does not seem to increase the number of young women who choose to enter these careers. Although attitudes toward women entering these careers may change with some forms of intervention, no significant behavior changes have resulted (Lantz, 1985). It is somewhat presumptuous to assume that interventions which focus on career choice should result in actual behavior change if the study of mathematics is at the heart of the problem. Those who are best prepared in mathematics in terms of actual course participation at the high school level are those who have the option of considering these careers. Research has repeatedly found that males are far more likely than females to participate in and excel at the highest levels of math study (e.g., de Wolf, 1981; Wise, 1985).

While some researchers have implied innate differences between the sexes in mathematical ability (Benbow and Stanley, 1980; 1983), many more have found a variety of sociocultural variables (e.g., gender role stereotyping, parent's perception of one as a learner of math) to be related both to mathematics achievement and enrollment in advanced mathematics courses (e.g., Sherman, 1981; Armstrong,1985). While these variables appear to exert a powerful influence on both math persistence and achievement, they are not readily amenable to interventions that produce behavioral changes. Thus, it has become necessary to investigate those variables upon which the educational community may have some influence. The conceptual model proposed by Fennema and Peterson (1985) holds promise as a vehicle through which reseachers can begin to understand, clarify and effect change in the area of females' math enrollment and achievement.

Autonomous learning behavior (ALB) was first proposed by Fennema and Peterson (1985) as a possible explanation for gender-related differences in mathematics. The behaviors that characterize ALB are viewed as mediators between internal and external influences and performance on high level cognitive tasks and are hypothesized to be the result of external and societal factors. ALB is hypothesized to include "working independently on high level tasks, persisting at such tasks, and choosing to do and achieving success in such tasks" (p.20). The model hypothesizes that the behaviors characterizing ALB are the mediators between external/societal influences, motivational variables, and gender-related differences in math achievement. Fennema and Peterson describe variables suspected to be included under this construct and several researchers have conducted studies examining classroom process and teacher-student interaction in an effort to identify ALB in the classroom. The present research obtained self-reports by students regarding ALB as defined by teachers and studied the relationship between gender, these teacher-defined characteristics of ALB, confidence in learning mathematics, and performance on routine and non-routine word problems and standardized math test scores. These three different problem-solving contexts were used for the dependent variables since context has been found to affect achievement differentially for females and males (Wentzel, 1988). ALB was defined by teacher-generated characteristics and self-regulatory and metacognitive strategies, as suggested by problem-solving research.

This research was a first attempt to operationally define ALB in an effort to suggest methods of intervention that could be used at all levels of children's education and at the preservice level in teacher training. If ALB is acquired over the general course of development by some individuals and not others, identifying ALB components that differentiate high and low math achievers will serve to aid in the development of different methods of intervention. Fennema and Peterson suggest that ALB cannot be learned during adulthood since they believe these behaviors develop over the course of general development. However, this is speculative. ALB must first be operationalized in order to determine its relationship to math performance and gender. Once the relationship between specific behaviors characterizing ALB have been identified, it will be possible to conduct developmental studies to investigate the levels at which different interventions may be appropriate. Thus, efforts to train individuals in the specific problem-solving behaviors engaged in by autonomous math learners and good problem-solvers, may be successful.

It was expected that ALB would predict achievement for each dependent variable significantly more than would either gender or confidence in learning math, but that ALB and confidence would be positively correlated. It was also expected that males would exhibit ALB to a greater extent than would females. Additionally, gender was not expected to add significantly to each prediction beyond ALB and confidence. Finally, the importance of each independent variable (i.e., gender, ALB and confidence) for predicting math performance scores was expected to vary across the three dependent variables (i.e., routine word problems, non-routine word problems and standardized math test scores).

II. REVIEW OF THE LITERATURE

Gender-Related Differences in Mathematics Performance

While females significantly outperform males on overall grade point average (deWolf, 1981; Besag & Wahl, 1987), a well-documented gender-related difference in math performance favoring males continues to haunt those concerned about educational equity.

Initial interest in gender-related differences in mathematics focused on discussions of math "ability" (Maccoby and Jacklin, 1974). The inference that differences in performance on a variety of mathematical indicators reflect differences in innate "ability" was rejected by many researchers in the educational community. More recently, the focus has been on exploring reasons other than innate "ability" to explain gender-related differences in math performance. While not every study agrees on the extent on these differences, in general the conclusion is that at certain points in their math careers, particularly at the highest level of math, males outperform females on a variety of math performance indices. Even when differences are small or approach significance, they are almost invariably in favor of males, and rarely, if ever, is the reverse true at the most advanced levels of math study.

Although research has found gender-related differences favoring males as early as the fourth grade (Peterson & Fennema, 1982), most findings suggest that junior high school is the level at which these differences first appear (e.g., Hilton and Berglund, 1974) and continue throughout the high school years. Hilton and Berglund (1974), using longitudinal data from an ETS study, found that females' math achievement was superior to males' before junior high school while males' achievement became superior beginning at the junior high level. Additionally, they divided their subjects into two groups: those who eventually went into an academic (college) track in high school and those who did not. Although at the 5th-grade level females in the non-academic group achieved at a higher level than did males in the non-academic group, by 11th grade, males' math performance was significantly better than females' both within and across the two groups.

Computation vs. Problem Solving

Research in computation skills at all levels has consistently reported either no gender-related differences or differences favoring females (Sherman, 1976; NAEP, 1979, cited in Armstrong, 1985; Dougherty, 1980, cited in Armstrong, 1985; Armstrong, 1985; Boswell, 1985). The findings for performance on tests measuring problem-solving skill are not as consistent. Sherman (1976) and Armstrong (1985) did not find gender-related differences in problem solving at the junior high level while other research suggests male superiority at problem-solving tasks at both the junior high and high school levels (NAEP, 1979, cited in Chipman & Thomas, 1985). Dougherty (1980, cited in Armstrong, 1985) found that while females performed better on computation tasks, males were superior on estimation and word problems with low computational demands.

<u>Gender-Related Differences in Math Achievement</u>

The research on gender-related differences in math achievement at the high school level is not consistent, though most disagreement appears to exist regarding the lower level courses, such as algebra and geometry. Differential performance by males and females is often exhibited in geometry as well as courses involving measurement and more advanced math (Fennema & Carpenter, 1981; deWolf, 1981; Chipman & Thomas, 1985). There appears to be a general agreement in the finding of lower performance by females when compared to males on the higher levels of math study (e.g., calculus, trigonometry). Wise (1985), using data from a subset of the 1960 longitudinal study, Project Talent, found small but significant differences in math achievement favoring males in the 9th grade and continuing through the high school years. Furthermore, the gains for males were more than twice the female gains, with gender differences increasing most sharply after 10th grade. Fennema and Sherman (1977) found gender-related differences favoring males, but these differences did not increase from grades 9-11. For this study, the gender-related differences also varied across the different schools sampled. In fact, findings from some schools indicated no gender differences. Although this is certainly a positive finding, it is also quite unusual.

While the pattern of male superiority in the more advanced math courses has been consistently established, there appears to be a relationship between math achievement and other achievement measures regardless of gender. Sherman and Fennema (1977) found that when students in the 10th and 11th grades were divided into two groups-- one that scored above the median of the distribution of math achievement by grade, and one that scored below the median--- both females and males in the top half of their class in math achievement scored significantly higher than the other group on measures of verbal and spatial ability. Thus, the dynamics of these performance differences may be far more subtle than gender explanations alone may indicate.

Standardized Tests and Other Indicators

Classroom math achievement is not the only area of math performance where differential performance by females and males has been documented. Scores on standardized aptitude tests such as the SAT consistently reveal gender-related differences in favor of males (ETS, 1979; Rosser, 1988). The studies conducted at Johns Hopkins University (Benbow & Stanley, 1980; 1983) revealed that for 7th grade gifted students with no formal training in advanced mathematics, the ratio of males to females who scored 500 or greater was 2.1:1. For scores of 600 or greater the ratio was 4.1:1 while the ratio for those who scored at the highest levels of 700 or greater was 13:1. The students who participated in this study were those who responded to a nationwide talent search in which any student in the top 3% on verbal or overall intellectual ability was eligible to take the SAT-M. Benbow and Stanley concluded that males exhibit higher math aptitude. However, participation was voluntary and there is no information as to the number of students-- or their gender-- who declined to participate.

Although the above research focused on a gifted population, other research reveals significant differences in the performance of females and males on the SAT-M for non-gifted populations. Chipman and Thomas (1985) report ETS results (1979) revealing that the average score for males is typically 40-50 points higher than the average score for females, with a 67 point difference for students in the top half of their high school class. Additionally, the number of males who receive very high scores on the SAT-M is much larger than the number of females who do so. ETS data on other math achievement tests reveal the same significant differences. Moreover, far fewer females choose to take the most advanced exam (Chipman & Thomas, 1985).

Although both classroom evaluations and standardized tests reveal gender-related differences in performance in favor of males, there appears to be greater and more consistent differences in standardized tests than in those measuring classroom achievement. Recent research suggests that "females and males may have different achievement goals and standardized testing and classroom evaluations afford the attainment of different goals for females and males" (Wentzel, 1988, p.697). In her longitudinal study, Wentzel examined achievement and standardized test scores and found that for males, achievement scores and grades consistently and significantly predicted one another over time. For females, achievement scores and grades were not reliable predictors of each other.

Other indicators of math achievement reveal that at the highest levels of performance, females are consistently underrepresented. Chipman and Thomas (1985) reported that at the High School Mathematics Contest in 1979-1980, of the 412,000 students competing, 254 were recognized on honor rolls for outstanding performance. Of these 254 students, less than 7% were females. During the years 1976-1985, the 55 students representing the United States at the International Math Olympiad have all been male. The Annual High School Math Contest has been ongoing for over 30 years and in that time, 20 perfect papers have been submitted, 19 by males and 1 by a female.

Gender Patterns in the Selection of Mathematics Courses

The number of mathematics courses taken as electives beyond the basic requirements in high school has been used repeatedly as a measure of persistence in math. Brush (1985) found that as early as the 7th grade, males plan to study math more and show a greater preference for math courses than do females. However, this gender difference is not reflected in the lower level math courses but in the more advanced courses (Sherman, 1976; Sherman & Fennema, 1977; Sherman, 1981; Chipman & Thomas, 1985; NAEP, 1978, cited in Armstrong, 1985). Indeed, in a study that attempted to determine the relationship between a variety of variables and the decision to enroll in further math classes, Sherman and Fennema (1977) were forced to eliminate the 9th grade because all students intended to take more math and the 12th grade because too few females were actually studying math. Studies conducted over the last 12 years are in agreement that overall, males do indeed take more math courses (Sherman, 1976; Sherman & Fennema, 1977; deWolf, 1981; Sherman, 1981; Wise, 1985).

Data collected by the Wisconsin Department of Public Education (1975-1976) revealed comparable enrollments in algebra and geometry but large gender differences in advanced courses such as trigonometry, analytic geometry, precalculus, and calculus (cited in Chipman & Thomas, 1985).

The trigonometry through calculus pattern of higher male enrollment was also found by the National Assessment of Educational Progress (1975-1976, cited in Armstrong, 1985). Similarly, Educational Testing Service (1979, cited in Chipman & Thomas, 1985) reported that 64% of males compared to 45% of females expected to have completed 4 or more years of math, with males often taking twice as many advanced math courses as females. Furthermore, 10th grade appears to be a critical period for females since gender differences in enrollment in mathematics courses sharply increase beyond this level, with males more highly represented in the higher level courses (Sherman, 1976; Wise, Steel & MacDonald, 1979; Wise, 1985).

It is important to note that females have always been represented in advanced math classes (Chipman & Thomas, 1985) and that, actually, few students of either sex continue to study math at the highest levels, with the number of females decreasing more rapidly than the number of males (Fennema & Sherman, 1977; Chipman & Thomas, 1985; Eccles, 1985). However, the differential representation of females and males at the highest levels is the issue with which present researchers are most concerned.

The Relationship of Course-Taking Behavior to Mathematics Achievement

A basic problem with many studies that found males out-performing females on measures of math achievement is their failure to consider the study of math (i.e., number and/or types of courses) in the data analysis or research design. That is, researchers claiming male superiority in math achievement often ignored the relationship between math achievement and math course-taking behavior. It is not surprising to learn that research has found number of math courses taken to be related to math achievement. Thus, considering the evidence that more males than females take advanced or "higher level" math courses, the findings of male superiority in math achievement can be re-examined more critically. As is typical of much research in the field of gender-related differences in math achievement, however, the findings of studies that consider math course-taking behavior in their design and analyses are inconsistent.

The classic Hilton and Berglund study (1974) that found gender-related differences in math beginning at the junior high level and continuing through the high school years, used students matched on <u>number</u> of courses taken. Thus, while these students had all taken 3 or 4 math courses in both grades 7 & 8, neither the type of course nor the content therein, was considered.

Using a sample consisting of several high schools, Sherman (1976) examined the relationship between gender and math achievement with training in math considered and found few gender-related differences in math achievement. When differences were found, they were small but in favor of the males.

Benbow and Stanley's work (1980; 1983) found large gender-related differences favoring males on the SAT-M for gifted 7th grade students. The researchers asserted that since these young students were not yet affected by any differential course-taking behavior, males possessed greater aptitude/ability for mathematics than did females.

Wise (1985) found several interesting results in his analysis of longitudinal data from a large sample of the 1960 Project Talent study. Math participation was measured by students' responses marked in the 1963 Student Information Blank and included algebra I, plane geometry, algebra II, solid geometry, trigonometry, analytic geometry or calculus. Math achievement was defined by students' scores on a 54 item test including 16 word problems to measure arithmetic reasoning, 24 introductory math items on elementary algebra and number theory, and 14 advanced math items for the 10-12th grades on plane and analytic geometry, trigonometry, and elementary calculus.

In the above study, Wise found that females in the 12th grade scored significantly lower than did males on the math achievement test when matched on participation in math and 9th grade achievement. Although the practical difference was considered small, it was significant and, favored males. Overall, gender-related differences in achievement were small when controlling for the amount of math courses taken.

When amount of math and earlier math achievement were NOT controlled, gender-related differences in math achievement were seen to increase eight times. Indeed, the two strongest predictors of math achievement were 9th grade math achievement and the amount of math courses taken in high school.

The relationship between math course-taking behavior, math persistence and math achievement is further complicated when one considers the findings of Pines (1980, cited in Chipman & Thomas, 1985). Pines found that gender-related differences in college math course participation were concentrated among students with the highest SAT-M scores. Males with high SAT-M scores but three or fewer years of high school math took more math courses in college than any other group of students. The comparable group of females took fewer math courses than any other group.

The National Assessment of Educational Progress (1979, cited in Armstrong, 1985), described the increase in the size of the gender-related difference in performance as the level of math participation increased as "striking." Thus, even when males and females participate equally in high levels of mathematics, gender-related differences not only do NOT always disappear, but may increase.

Possible reasons for these results must be explored. What is it about this high level material that causes females to lag behind males in performance? What are the skills necessary to perform well on high level math tasks, whether they are word problems at the junior high school level or advanced math at the high school level? More specifically, what behaviors, strategies, attitudes or approaches to problem-solving differentiate the good from the poor problem-solver? The Autonomous Learning Behavior model suggests some variables worth exploring to address this question. But before discussing the ALB model and literature relating to the variables defined therein for this research, this paper will now review previous models that have been proposed by others in the field.

Models that attempt to explain gender differences in performance, persistence and math career choice take several forms and will be discussed here in two basic categories of outcome variables: 1) math performance, persistence and/or intention to take math courses, and 2) choice of quantitative career.

Models of the Relationship between Gender and Mathematics Achievement, Participation and Intention for It's Continued Study

Wise and Project Talent. Using a subset of the 1960 Project Talent participants, Wise (1985) analyzed data on 7500 students who were tested and surveyed as 9th graders in 1960 and as 12th graders in 1963. In all, subjects represented

118 schools from different size regions and economic levels. The dependent variables included math achievement in twelfth grade, as measured by a 54 item test, and math participation through high school. Independent variables included sex, subject's family background, cognitive and social-psychological attributes in the 9th and 12th grades, experiences during high school, school characteristics, math level of expected occupation, math level of expected college major, and interest in math and math-related careers.

The two strongest predictors of 12th grade math achievement were 9th grade math achievement and amount of math taken in high school. These variables together had a multiple R of .84, accounting for over 70% of the variation in 12th grade math achievement. For students with the same amount of math participation, initial "abilities" were highly predictive of final level of achievement; however, the amount of math taken also had a strong effect on twelfth grade math achievement independent of initial "abilities". When ninth grade math achievement was used as a covariate, females with math participation and math ability equal to the males' still had lower scores than the males. Though this finding was significant, it was not large. Three additional predictors of gains in high school math achievement were general academic aptitude, interest in math and math-related occupations relative to office work, and low levels of participation in extracurricular activities in ninth grade. Although this model applied to both females and males, some significant gender differences did emerge. For males, scientific attitude and electricity and electronics knowledge were also significant predictors of math achievement while for females, socioeconomic status, low immediate concern with earning a living, and sports knowledge were significant predictors. Although self-confidence was important for both females and males, it was a much more significant predictor of math achievement for females.

The largest predictor of math participation through high school was ninth grade math achievement. After controlling for ninth grade math achievement and educational expectation, the significant gender difference in math participation was predicted by measures of interest in math and in math-related careers relative to interest in office work. After controlling for the above variables plus college preparatory curriculum, the following variables interacted with gender as correlates of math participation. For males the variables were table reading, visualization in three dimensions and information about foreign countries. Additionally, those males who discussed plans with couselors more frequently in the ninth grade had lower participation rates. For females those variables significantly correlated with math participation gains were prestige and math level of the father's occupation, number of times in the ninth grade that post-high school plans were discussed with the father and NOT with a school counselor, and parental expectations regarding college. Two characteristics of school and school environments were found to predict higher than expected participation levels for females but not for males. These were the percentage of parents in the PTA and the frequency of standardized testing.

Finally, the LISREL IV program was used to test structural models developed by incorporating those independent and moderator variables found to have the strongest relationships to math participation and achievement. The model attempted to explain how gender and other independent variables relate to high school math participation and achievement, and is shown in Figure 1. Three basic statements can summarize this model. First, the strongest direct predictors of 12th grade math achievement were amount of math participation in high school, 9th grade math achievement, and overall 9th grade academic "ability". Second, other variables of significance were 9th grade interest in math, 9th grade interest in math-related careers, 9th grade math level of expected occupation, and 9th grade expected level of education. Third, the effect of gender was always indirect. That is, the effect of gender operated through females' lesser interest in math, lesser interest in math-related careers, and lower math level of planned careers. According to Wise,

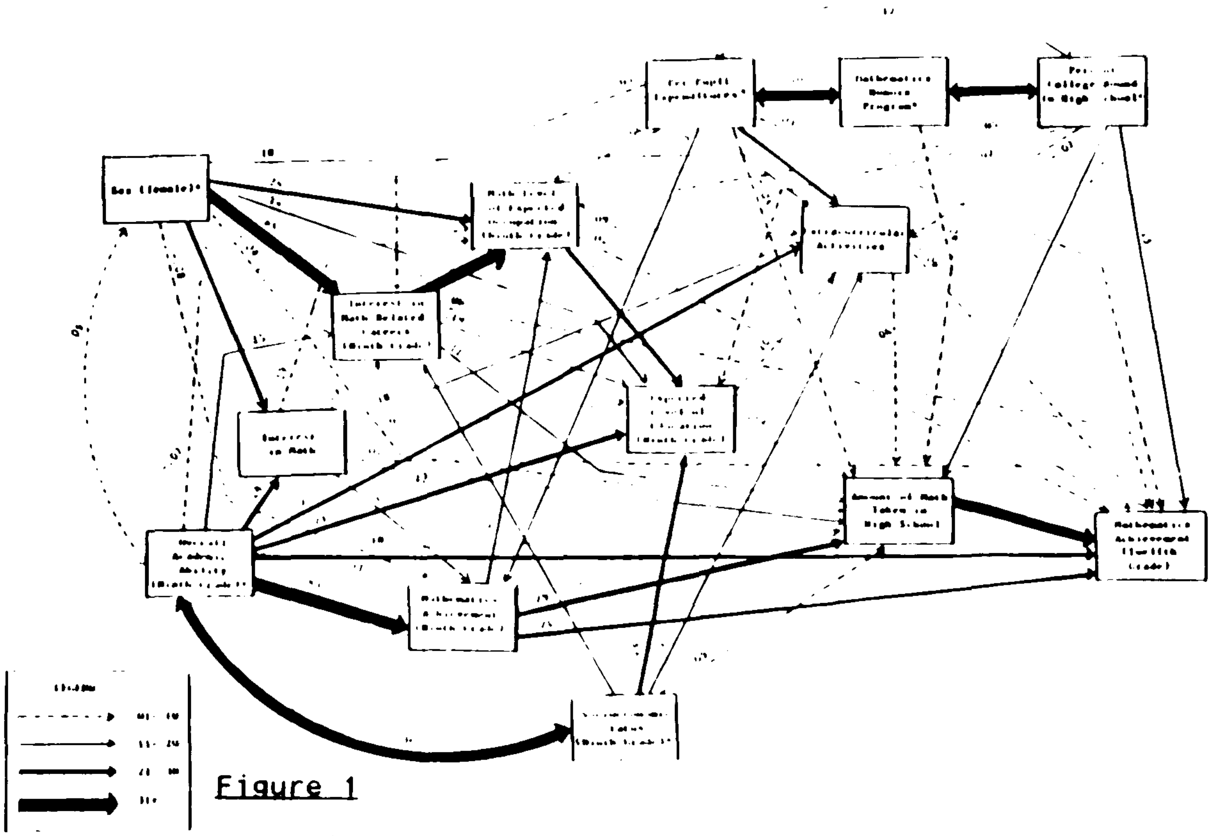


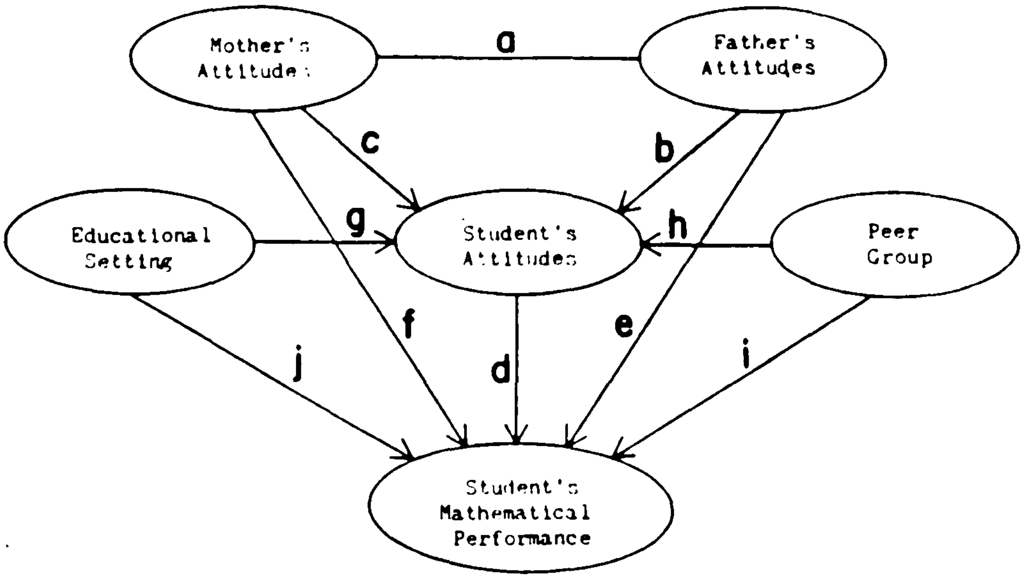
Figure 1

Wise's path model of the relationship of gender and other independent variables to math achievement based on Project TALENT data. From: Project TALENT: Mathematics course participation in the 1960's and its career consequences. In S.F. Chipman, L.R. Brush & D.M. Wilson (Eds.O. Women and mathematics: Balancing the Equation. Hillsdale, N.J.: Erlbaum.

"the observed sex difference in math achievement by the end of high school can thus be explained by differences in career interests and plans which are evident at the beginning of high school and which strongly influence the number of high school math courses taken" (p.45).

Boswell's model. Boswell (1985) presented a model that reflects the relationship between parents, peers, educational setting, and students' attitudes and performance in math. The model presents a variety of sociocultural variables as important factors in females' math attitudes and achievement. Figure 2 depicts this model which includes those general variables seen to impact on the outcome variables, and the inter-relationships among the predictor variables. Boswell believes that sex role stereotyping of mathematics is the basic problem for women and adversely affects their achievement in this area. She focuses on three factors that discourage or prevent females from entering math-related fields or succeeding in this area. These are a) external structural barriers, defined as overt sex discrimination, b) social pressures from "significant others such as parents and peers", and c) internal barriers, defined as internalized negative attitudes toward math. This last factor is discussed in another section of this paper (see p.47), but the results for variables predicting math achievement and discrepancy scores are presented here.

For both females and males, non-language aptitude score



LEGEND
a agreement between mother's and father's attitudes toward mathematics
b influence of father's attitudes upon student's attitudes toward mathematics
c influence of mother's attitudes upon student's attitudes toward mathematics
d influence of student's attitudes upon performance in mathematics
e influence of father's attitudes upon student's performance in mathematics
f influence of mother's attitudes upon student's performance in mathematics
g influence of educational setting upon student's attitudes
h influence of peer group on student's attitudes
i influence of peer group upon student's performance in mathematics
j influence of educational setting upon student's performance in mathematics

Figure 2

Boswell's model reflecting the relationship between parents, peers, educational setting, and students' attitudes and performance in mathematics. From:The influence of sex-role stereotyping on women's attitudes and achievement in mathematics. In S.F. Chipman, L. R. Brush & D. M. Wilson (Eds.). Women and Mathematics: Balancing the Equation. Hillsdale, N.J.: Erlbaum.

was the highest predictor. For males, important predictors were also positive math attitudes and interest in "male" occupations in the eleventh grade. For females, other important predictors were a math stereotyping scale, intellectual achievement, math attitudes and interest in "male" occupations.

Discrepancy scores for this study were basically a measure of underachievement in math. That is, this variable was defined as the difference between each student's math aptitude ant their achievement scores. Although no gender differences were found in the analysis of variance on the discrepancy scores, further correlational analyses revealed an interesting relationship among attitudinal and other personality variables and discrepancy scores. For both females and males, a smaller discrepancy existed when students held positive as opposed to negative math attitudes and interest in traditional "male" occupations. Additionally, for females, underachievement also correlated with stereotyping of math as a male activity and the father's stereotyping of the subject. Thus, the focus of Boswell's model is on sociocultural variables that reflect a contextual aspect since different peer and family attitudes, homes and educational settings can vary across individuals and school systems rather than simply across gender. Realistically, though, sociocultural forces are quite powerful and not easily amenable to intervention.

Armstrong's predictive models. Armstrong (1985) investigated shifts in attitudes and achievement in mathematics during the high school years and used a large sample of 13 year old students in the 8th grade, and 12th grade students. A 90 minute survey assessed the following variables: achievement, defined by performance on computation, algebra I and II, problem solving, and spatial visualization; four levels of participation in math courses and intended participation for the eighth grade students; gender role stereotyping as measured in general, for math as a masculine area, and males' attitudes toward females who are successful at math; parental influence and background information such as grade, SES, parents' education, and parents' occupation. Using regression techniques, eight predictive models were generated, four each for the prediction of mathematics achievement and participation for each gender and grade level.

The variables were separated into three categories before entrance into the regression analysis. These were a) nonintervenable variables such as school enrollment, availability of math courses and SES; b) characteristics of others; and c) characteristics of self. A summary of the predictive models for both outcome variables are presented here. For both females and males at both grade levels, the characteristics of others and characteristics of self categories predicted variance well beyond that explained by the nonintervenable variables for both achievement and participation. For both females and males at the 12th grade level, the three categories explained 38% of the variance in mathematics achievement. However, nonintervenable variables alone accounted for only 6% of the variance for males but 12% for females. While similar increases in predictability were seen for both genders with the addition of the categories of characteristics of self and others, the variables within these categories differed somewhat in type and importance. For males and females the characteristics of others included teacher encouragement, mother as a role model, and parental encouragement. However, for males mother's educational expectations was important while for females father's educational expectations and counselor encouragement helped increase the prediction. In the characteristics of self category the variables attitudes toward math, educational aspirations and math preparation required for job were significant predictors. Additionally, the variable career aspirations increased the overall prediction for males to the same degree as the females' without the inclusion of that variable.

For the eighth grade sample, nonintervenable variables for both females and males were school enrollment and SES. The characteristics of others category included the following variables for both females and males: teacher differential treatment, father's educational expectations and counselor encouragement. The inclusion of these variables increased the prediction of math achievement for males an additional 10%. For females inclusion of another variable, mother as a role model, was an important predictor and the whole category increased the prediction of math achievement over nonintervenable variables by 20%. The third category, characteristics of self increased the total predicted variance to 19% for males and 26% for females. This category included the variables attitudes toward mathematics, stereotyping of women, and educational aspirations for both females and males. Additionally, for males locus of control was included in the model while for females, school anxiety was a predictor.

The predictive models for math participation reflect similar patterns with nonintervenable variables accounting for far less of the variance than in the achievement models. For both females and males at the twelfth grade level, the categories of other and self increased the predicted variance to 37% and 39% respectively. The characteristics of others category revealed some interesting differences between the genders. The only variable in common for both females and males was father's educational expectations, the best predictor in that category for both genders. Additionally, for females teacher encouragement and teacher stereotyping were significant predictors, increasing the predicted variance to 28%. For males, the variables counselor encouragement, mother as a role model, parental encouragement, and mother's educational expectations were important predictors, increasing the predicted variance to 31%. The final category, characteristics of self, included the same variables for both genders. These were mathematics preparation required for a job, educational aspirations, and attitudes toward math.

For the eighth grade students the model predicting participation revealed that for this age group nonintervenable variables account for little or no variance-- 2% for males and 0% for females. The two variables for females and males in the other category were different. At this age, mother's educational expectations and parental encouragement increased the prediction to 10% for males. For females counselor encouragement and father's educational expectations increased the predictive ability of the model by 7%. The self category contained the same variables for both genders. These were usefulness of math, attitudes toward math, and educational aspirations. While this category was the only one of any of the models to contain the same variables in the same order for both females and males, this self category increased the predictive ability of the model by 9% for males but only 2% for females over the former two categories.

In summary, in the Armstrong study data there appears to be an interaction of age and gender accounting for differences in the predictability of the characteristics of self and others for math achievement and participation. For 12th grade students, there was only a 1% difference in the increase between the addition of the self category for females and males in predicting math participation. At the 8th grade level, the difference was a 9% increase for males and a 2% increase for females. Thus, at the earlier grade level, males' self characteristics increased the predictive ability of the model far more than did the category for twelfth grade males, while for females these self characteristics increased the prediction by only 2%. Perhaps it is this self category that is important at this grade level where males express the self as an important component of decisions regarding mathematics. This may be an important stage at which to attempt interventions that increase the expression and power of self for females in the important area of math achievement and participation.

In the models predicting math achievement, at the 12th grade level the addition of the self category added 7% for females while only increasing the predictabilty by 3% for males. However, at the eighth grade level the self category increased the predictability of the model by 6% for males and only 3% for females. Therefore, the junior high school level appears critical to examine since expressions of self for females at this level adds far less to the prediction of math achievement than the self category at the high school level. Moreover, the self category may be a component of confidence in learning math, which may be a more important predictor for females at the high school level. Thus, Armstrong's findings suggest that not only do different sociocultural and self variables impact differently on females and males, but that these differences manifest themselves at different developmental levels. Because this is not a causal model one cannot assume paths not specifically delineated; however, research may find that the self variables are dependent on the other variables and they may not easily be separated qualitatively.

A study of females in advanced mathematics programs. Casserly and Rock (1985) studied factors thought to affect females' enrollment, perseverance and achievement in advanced and extensive mathematics programs at the high school level. The eight schools chosen for this research represented a variety of areas across the United Stated, incuding Hawaii. This is important since many cultures were represented by this sampling, although the school did need to meet specific criteria for advanced placement math courses and high females participation. Thus, the schools studied may not at all be representative of an average American school where such programs may not be available. The select sampling, however, afforded the opportunity to investigate variables affecting many young women who are successful in mathematics.

In this longitudinal study, Casserly and Rock administered questionnaires and conducted interviews at two points over a two year period. The first year measures yielded data in three main categories: a)general background incuding family information, SES and aspirations; b) particular school histories; c) perceptions about math, and gender roles; and d) perceptions of future adult activities. Second year measures revealed information on experiences in math over the former year, long-range goals and factors affecting curricular choices. Additionally, information was obtained regarding students' perceptions of the importance of their advanced math work and its relevance to college and career. It is important to stress that all the young women involved in this research were students in advanced placement math classes, making them a select sample of female students.

The authors' original conceptual model defined three outcome variables: persistence in mathematics, career aspirations, and educational aspirations. The path analysis model, formulated after data collection (see Figure 3), describes the inter-relationships among the variables, keeping the three original outcome variables. This path analysis model reflects patterns for females in the advanced placement calculus classes, thus this may not necessarily be a general model of math persistence and/or career and educational aspirations for all females. Direct predictors

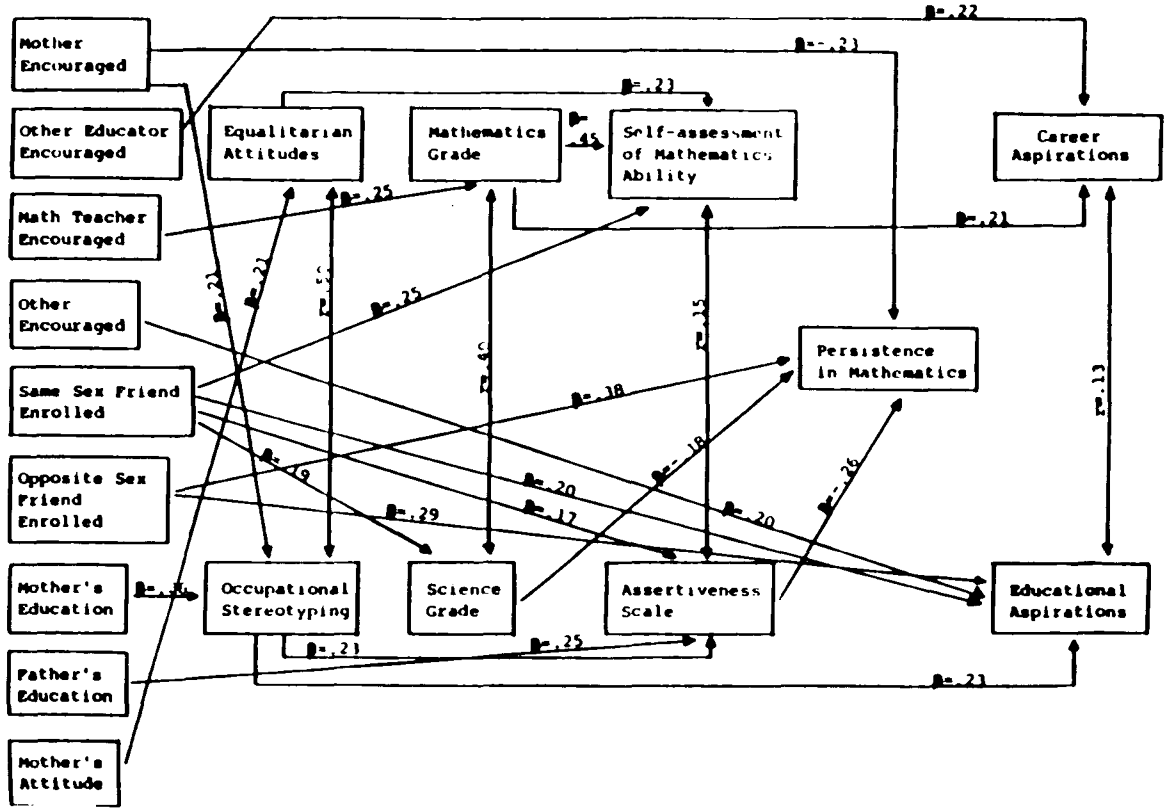


Figure 3

Casserly and Rock's path analysis model for women in advanced placement calculus classes. From: Factors related to young women's persistence and achievement in advanced placement mathematics. In S.F. Chipman, L.R. Brush & D.M. Wilson (Eds.). Women and Mathematics: Balancing the Equation. Hillsdale, N. J.: Erlbaum.

of persistence in mathematics included mother's encouragement, having a male friend enrolled in the math class, science grade, and assertiveness. Direct predictors of career aspirations were teacher (in subjects other than math) encouragement, mathematics grade and educational aspirations, while direct predictors of educational aspirations were career aspirations, occupational stereotyping, male friend's enrollment, female friend's enrollment and encouragement from those other than teachers, friends or parents.

A variety of socio-psychological variables were found to be inter-related or related to such self variables as equalitarian attitudes and self-assessment of math ability. The relationship between father's education and persistence in math was mediated by a measure of assertiveness, while self-assessment of math ability (as a outcome variable) was predicted by father's education, with the assertiveness measure as a mediating variable, and by mother's attitude when mediated by equalitarian attitudes. Thus, for this particular group of young women, while many sociocultural and two psychological variables were inter-related, contrary to the findings of much research using a less select population, few sociocultural variables appeared to have a direct impact on persistence in math for these females who exhibited advanced achievement in math. These findings suggest that factors other than those traditionally defined as sociocultural may be operating for females who excel or persist in the study of math. However, since this research did not include any measures of study behaviors or other cognitive or metacognitive components, it is difficult to interpret the sparse relationships between specific variables. It is interesting to note that mathematics grade was a direct predictor of career aspirations for these young women, although this variable was unrelated to educational aspirations.

Eccles et al.: A socialization model predicting intention to take mathematics. Eccles, Adler, Futterman, Goff, Kaczala, Meece and Midgley (1985) conducted a thorough and informative study with a different focus than those previously discussed. They investigated determinants of students' course selection in math based on a general model of academic choice by examining a variety of sociological, psychological and cognitive variables. The researchers hypothesized that "the extent to which boys and girls differ in their interpretations of outcomes and the extent to which they receive different information relevant to their expectations of success and to the value of various achievement options might account, in part, for the observed sex differences in students' enrollment in math courses" (p.98).

A two year cross-sectional/longitudinal project was designed using 339 students in grades five through eleven in the first year and 668 students in the second year -- 329 for the control group and 94% of the original first year group. A path model based on the second year data revealed the following relationships among several student attitudes and the intention to take more mathematics. Figure 4 depicts this model. Intentions to continue the study of math were most directly influenced by perceived value of math and current and future expectancies for math performance. These variables were related to students' estimates of both their own math ability and that of their parents' and their teachers' beliefs regarding their math ability. Past math performance did not have a direct effect on students' intention to take more math, on their expectancies for current or future performance, or on their subjective estimates of their own math ability or the difficulty of math. Stereotyping math as a masculine domain increased the value of math and of expectancies for future performance, regardless of the subjects's gender. This model explained approximately 36% of the variance in intention to take mathematics.

Although the following results were not part of the model, they deserve mention in this discussion. While few gender differences existed on both standardized test scores and course grades, males rated their math ability higher, felt they had to exert less effort to do well in math, and held higher expectancies for future successes in math. Also

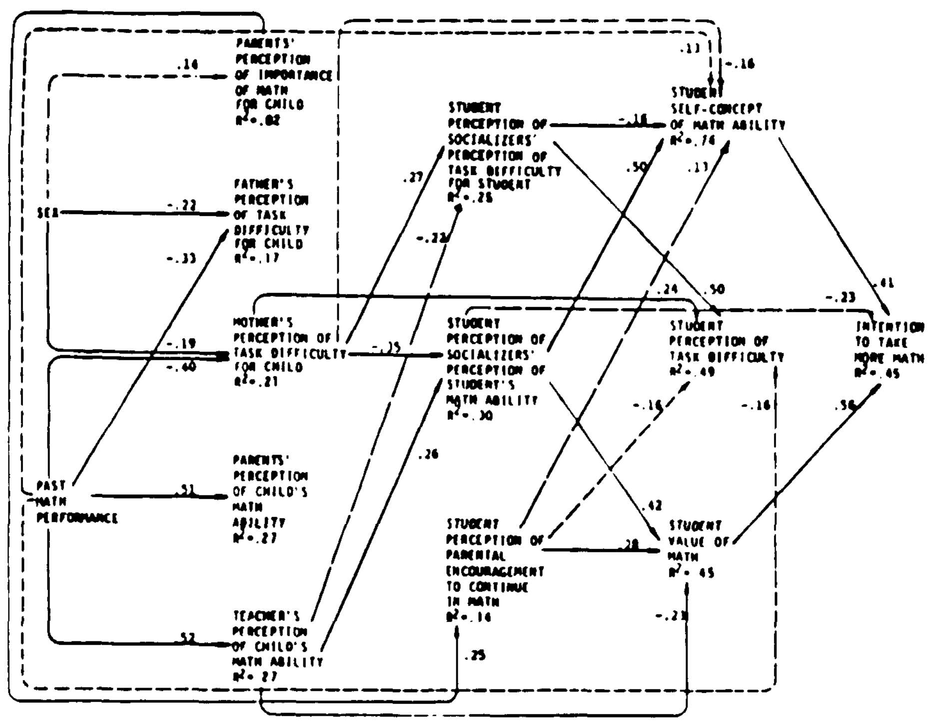


Figure 4

Path analysis model presented by Eccles et al. for their test of a socialization model predicting intention to take mathematics. From: Self-perceptions, task perceptions, socializing influences, and the decision to enroll in mathematics. In S.F Chipman, L.R. Brush & D.M. Wilson (Eds.). Women and Mathematics: Balancing the Equation. Hillsdale, N.J.: Erlbaum.

interesting were the results that all students rated math as more useful for males and males rated the importance of future plans in their decision to take more math higher than did females. Additionally, while students did not rate males as having more ability in math than females, males did feel their counselors provided them with more encouragement than did females. The relationship between gender, usefulness of math and value of math was interpreted by Eccles et al. in a manner which suggests that the status of the job rather than its domination by males may be what increases the perceived usefulness of mathematics. Thus, the perception that math is a masculine activity may not be detrimental to females' performance or overall attitudes in math.

The choice of fields of study involving mathematics. A recent study into influences on females' selection of fields of study involving mathematics revealed relationships among variables of interest that have been discussed previously. Ethington and Wolfle (1988) used a nationwide sample of students beginning in 1980 and surveyed them again in 1982 and 1984. The results discussed here are based on the 1312 young women who participated in all three phases of the study.

Three groups of independent variables were used. A first group of exogenous background measures included SES, race, self-concept, locus of control, sophomore choice of field of study and attitude toward math. A second group of endogenous variables included number of math/science courses, parental influence, school influences, sex role orientation, and family orientation. The third group of variables included high school grades and science and math achievement. The three most influential predictors in the model are presented here.

Mathematics and science courses taken in high school was the only variable other than the background measures that had a direct influence on choice of field of study. This was not a surprising finding and is indeed in agreement with the research of Carney and Morgan (1981), Peng and Jaffe (1979) and others (Dunteman et al., 1979; Ware et al., 1985, cited in Ethington and Wolfle, 1988). Number of math and science courses taken was the variable with the largest direct effect.

The second most influential predictor was sophomore choice of field of study, having both direct effects on the dependent variable and indirect effects through the number of math and science courses taken. This finding assists in clarifying research finding the sophomore year in high school to be a critical period for females in their mathematics course-taking behavior (Sherman, 1976; Wise, Steel & MacDonald, 1979; Wise, 1985). Thus, there is good reason to investigate specific behaviors at the junior high school level since important behaviors regarding these decisions are either developing or extablished at this point. Interventions may be introduced at this time to influence certain behaviors characteristic of those who achieve well in math and choose to continue this area of study beyond basic requiremnts.

The variable with the third largest total effect was attitude toward math, which had both a direct effect on choice of field of study and an indirect effect mediated through the number of math and science courses taken.

Summary. In summary, although controlling for certain variables may decrease the advantage males have in math achievement, they continue to outperform females, particularly at the highest levels of math study. Additionally, males persist longer at mathematical tasks and choose to study the highest levels of mathematics more often than do females. While it is interesting to research and discuss relationships between these dependent variables and those that are sociocultural, educators have not been able to effectively deal with this problem with the knowledge gained from this information. Sociocultural forces take generations to change. It appears counter-productive to attempt to alter these variables and far more productive to investigate behavioral characteristics and strategies of those students who excel in math, particularly in problem-solving. While the Autonomous Learning Behavior Model considers external/sociocultural factors, they are background variables and not those considered to directly impact on gender differences in math achievement. Rather, this model posits that these sociocultural variables, along with internal cognitions of attributions for success and failure at mathematical tasks and attitudes toward math (motivational variables) are mediated through Autonomous Learning Behavior to affect math achievement. The following section presents a discussion of Autonomous Learning Behavior as proposed by Fennema and Peterson (1985) and operationalizes the variables that will be used in this research to define Autonomous Learning Behavior (ALB).

Autonomous Learning Behavior Model

Figure 5 depicts the conceptual model proposed by Fennema and Peterson (1985) to explain the development of gender-related differences in mathematics achievement. Since the variable differentiating this from other models is Autonomous Learning Behavior, it will heretofore be referred to as the Autonomous Learning Behavior (ALB) Model. ALB is hypothesized by these researchers to be a possible explanation for gender-related differences in mathematics, with the concept being derived from literature suggesting that in general, females are socialized to be more dependent than are males (e.g., Maccoby & Jacklin, 1974; Kramer, 1988). While a main objective of education is to prepare

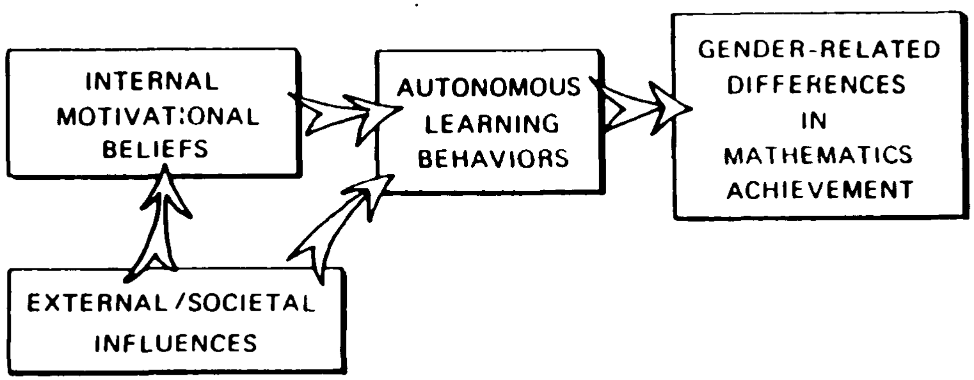


Figure 5

Autonomouns learning behavior model proposed by Fennema and Peterson. From: Autonomous learning behavior: A possible explanation of gender-related differences in mathematics. In L. C. Wilkinson & D. B. Marrett (Eds.). Gender Influences in Classroom Interaction. N.Y.: Academic Press.

students for independent learning, Fennema and Peterson assert that schools engage in behaviors that reinforce the socialization patterns of society in general. Thus, females and males may approach learning tasks differently depending on behaviors that have been previously reinforced or punished through the process of socialization.

Fennema and Peterson hypothesize that the behaviors that characterize ALB are developed over the course of a child's general development and that these characteristics are learned "as one is allowed, forced, or expected to exhibit them" (p.21). Additionally, they assume that "greater participation in autonomous learning activities leads to greater development of ALB which, in turn, leads to greater performance on high cognitive level tasks" (p.21). While these behaviors may be important for general learning, it is possible that they are essential for achieving highly in mathematics. Mathematicians describe themselves as independent learners who find satisfaction in solving high level problems and are seen as persistent and choose math activities that are challenging and stimulating (Gustin, 1982; Helson, 1980). Grieb and Easey (1984) assert that independent learning is particularly important to grasp the conceptual framework of math necessary for the highest level cognitive math tasks.

Research Related to the ALB Model

Fennema and Peterson (1986) tested their hypothesis regarding ALB in a study that examined classroom processes at the 4th grade level. Subjects completed a math test containing low and high cognitive level items in December and May and the researchers randomly selected 6 females and males from each of the 36 classrooms for observation and data on teacher-student interaction. They found that girls' engagement in social activities, in one-to-one interaction with a teacher and receiving help from a teacher were negatively related to girls' higher level math achievement. The researchers suggest that "these classroom processes reflect a dependence on others that may be counterproductive for the kind of independent thinking that is needed to solve a high-level mathematics problem" (p.11). According to Fennema and Peterson, teachers may be instrumental in the development of independent thinking, self-direction and autonomy in that they should encourage students to solve math problems on their own without reliance on them.

Hudson's research (1986) also lends support to the concept of ALB and its relationship to math achievement for females. Using data from the 1977-1978 and 1981-1982 NAEP math assessment studies, she performed item-level analyses and examined students' attitudes and beliefs in math. In agreement with much of the prior research in the area, Hudson found that gender differences were indeed related to item difficulty and content. Her findings that females performed worse than males on less familiar items was of particular interest to the present study, which was interested in routine versus non-routine word problems. Hudson's finding on familiarity also supports the notion that difficulties arise for students when they do not have a routine way of solving a problem, or the routine solutions attempted lead to errors (McLeod, 1987). Unfamiliar tasks also related to lower confidence levels for females.

While Hudson found gender differences in learned helplessness when measured as attitudes and beliefs, her results indicate that confidence may account for these gender differences better than the concept of learned helplessness. However, Hudson asserts that "helplessness" may be most difficult to detect with attitudinal or belief questionnaires and that the helplessness that may contribute to girls' lower math achievement is a "subtle phenomenon that is best measured behaviorally" (p. 118).

Other researchers have taken a different approach to defining ALB and have examined teachers' behaviors and their relationship to student math achievement. Koehler (1985) examined teacher behavior in the classroom in an effort to delineate those behaviors that do or do not foster ALB. She defined the following behaviors as those likely to not foster ALB in the classroom: willingness to give help or be available for help in problem-solving and amount of encouragement students were given to ask questions. Conversely, behaviors defined as those likely to foster ALB were an unwillingness to give help or to be less available for help while students engaged in problem-solving and the non-encouragement of students' questions in class. By examining these classroom processes at the 9th grade level, Koehler found that the teacher who fostered more ALB had students with higher math gain scores. In the class with lower gain scores, students were more dependent on the teacher and on each other during problem-solving activities. This class also had an intriguing statistic -- the students asked "Is this right?" quite often. This finding is interesting since pilot research for the present project indicated that some teachers may indeed believe that good problem-solvers and autonomous math learners are interested in knowing whether or not their answers are correct. Considering that in Hudson's study, this was characteristic of the class with lower math gain scores, the present project suggests that some teachers may define ALB differently than does research. Koehler concluded that an effective technique for producing math gains in females may be for teachers to engage in active teaching and foster ALB in students. Unfortunately, these results may not be generalizable since the findings on ALB come from data collected in two "honors" math classes. Still, these findings suggest that specific behaviors that define ALB and that are necessary for successful problem-solving may be unrelated to "aptitude."

The developmental aspect of ALB was examined by Kontos and Nicholas (1986). Although the researchers did not use the term ALB in their study, the method and results are consistent with other ALB research and further allude to the developmental component originally supported by Fennema and Peterson (1985). Kontos and Nicholas investigated the impact of adult guidance on children's problem-solving performance using pre-school, kindergarten and second grade students. The problem-solving task was a unique and unfamiliar peg-board type puzzle. The experimental group received adult instruction for solving the puzzles during two of the five days in which the puzzle-solving task was presented. Four measures of problem-solving performance were taken daily-- number of pieces placed; seconds to first piece placed; strategy presence; and number of strategies. They found no main effects for treatment group-- adult guidance was not a necessary precursor to improvements in children's problem-solving performance. Kontos and Nicholas concluded that self-initiated problem-solving activity plays an active part in the acquisition of cognitive and metacognitive skill. Thus, at these early levels of problem-solving, children apparently need to find the strategy best suited to their age level for a particular activity. It would have been most informative had the research been carried a step further. Perhaps the second-grade children could have aided the younger students with information on their strategies. Although adult interaction was not helpful, strategies used by peers may be more easily understood and applied, even if the "peer" is two years older.

Fennema and Peterson believe the behaviors that define ALB cannot be learned in adulthood since they are part of the general developmental process. However, the literature suggests that ALB, as conceptualized by these researchers, may be at least partly defined as math metacognitive and self-regulatory behaviors. If ALB, as behaviorally defined by teachers, is found to differentiate between good and poor problem solvers or females and males, interventions using these strategies may be effective for improving problem-solving skills.

The present research shed light on two questions posed by Fennema and Peterson, since certain aspects ALB and gender have not yet been empirically answered. These are: "Do girls and boys actually participate differently in ALB?" and "Does more participation in ALB result in higher achievement?" The following section presents the variables this project will be using as the operational definition of ALB-- math metacognition and self-regulation, and a brief overall review of the math attitude literature focusing on confidence in learning mathematics. The relevance of these variables to Fennema and Peterson's discussion of ALB will be presented along with a brief review of the relevant literature for each variable.

Operational Definition of Autonomous Learning Behavior

Self-Regulation

Fennema and Peterson partially define ALB as working independently on high level tasks and persisting at these tasks. Thus, one method of defining ALB for this research is self-regulation of math learning. While no research projects have investigated gender differences in self-regulation during different phases of problem-solving, there has been a good deal of work done on self-regulation as it relates to achievement in general. This section presents a discussion of self-regulation theory and some empirical research findings for its use in the classroom.

While self-regulation theory has its roots in behaviorism, its expansion into the present-day cognitive conceptualization lies in the interpretation provided by Bandura and cognitive social learning theory. That is, the triadic system of person, environment and behavior are reciprocal and provides a more complete explanation of human choice and behavior. According to Bandura (1986), "neither intention nor desire to change alone has much effect if people lack the means for exercising influence over their own behavior" (p.336). Thus, the concept of self-regulation or lack of it may help educators to understand why females exhibit inferior achievement on high level math problem-solving tasks when compared to males and fail to persist in the study of mathematics at the highest levels. While females may exhibit a desire to study mathematics, may have indeed achieved in previous courses, and may have the necessary prerequisite knowledge to excel at the higher cognitive levels, they may lack the behaviors necessary to regulate the learning of high level concepts or master unfamiliar types of problems.

Bandura defines the subfunctions of self-regulation as self-observation, judgmental processes and self-reaction and asserts that all three are necessary for successful regulation of one's own behavior (Bandura, 1986). Individuals not only change their own behavior during self-regulation but also shape their environments in the process. This may be particularly important as it relates to the behaviors and achievement of females in the typical mathematics classroom.

Zimmerman (1986) describes self-regulation theory as viewing students as metacognitively, motivationally, and behaviorally active participants in their own learning and defines underachievers as those who "may not be adept at controlling contextually specific cognitive, affective and motoric learning processes" (p.307). Indeed, several studies have found the use of a variety of self-regulation techniques to positively affect academic achievement

(Zimmerman & Pons, 1986; Schunk, 1986; Henderson, 1986) and math achievement in particular (Sagotsky, Patterson, & Lepper, 1978). Using a structured interview, Zimmerman and Pons (1986) found the use of self-regulated learning strategies to differentiate high and low achievers at the 10th grade level. Further, in regression analyses use of these strategies was a better predictor for both English and Mathematics sections of a standardized achievement test than were either gender or SES.

In summary, it appears important to partially define ALB in terms of self-regulation as an indicator of independent math learning, but insufficient as the sole definition. Although metacognition is considered to be a subfunction of self-regulation, this research found it imperative to include a separate review of metacognition, particularly as it relates to math, since a different body of literature is involved. Perhaps the difference can best be explained by describing self-regulatory processes as "thinking about performance, goals, and rewards" while metacognitive processes specific to the context of mathematics might best be described as referring to "one's knowledge concerning one's own cognitive processes and products or anything related to them .... it refers to the active monitoring ... of these processes in relation to the cognitive objects or data on which they bear, usually in the service of some concrete goal or objective" (Flavell, 1976).

Metacognition

Metacognitive researchers are in agreement that good problem-solvers do not necessarily possess more knowledge than do poor problem-solvers, but they possess superior use of specific strategies and an awareness of their thinking processes (Flavell, 1976; Garofalo & Lester, 1985; Schoenfeld, 1987; Lester & Garofalo, 1987; Peterson, 1988).

Flavell and Wellman (1977) discussed knowledge about cognition in terms of the importance of person, task or strategy and considered the interactions of these variables specific to problem-solving. Garofalo and Lester (1985) identified 2 aspects of metacognition; knowledge of cognition, with knowledge categorized according to its influence on person, task and strategy ; and regulation of cognition, which includes monitoring and self-corrective behaviors. While these variables are more contextually specific to problem-solving, one can see the relationship between these variables and those considered important to cognitive social learning theorists. That is, the importance of the reciprocal functions of person, enviroment and behavior. Similarly, Schoenfeld (1984) defined three levels of knowledge and behavior: personal resources, control, and belief systems.

Garofalo and Lester further elucidate the importance of person, task and strategy by suggesting examples of interactions. For example, a person x strategy interaction may include the individual's familiarity with and confidence in using potentially useful strategies. An example given of a task x strategy interaction is the student's awareness that certain classes of problems can be solved using a certain heuristic or that certain types of word problems may require the student's reading them more than once to gain a more complete understanding. Indeed, Silver (1982) found that problem-solving attempts can be affected by the student's awareness that more than one strategy can yield the correct solution.

Self-regulation researchers appear to view metacognition as a subfunction of self-regulation while metacognition researchers appear to view self-regulation as a subfunction of metacognition. Either way, the two are seen as closely related and important to successful problem-solving (Corno, 1986; Wang & Peverly, 1986). Schoenfeld (1987) delineates four aspects of metacognition as a) understanding the problem; b) planning; c) monitoring; and d) allocating resources. According to Schoenfeld, good problem-solvers test and reject ideas, are aware of their thinking processes, make tentative explorations, generate approaches and try new approaches when warranted. Additionally, good problem-solvers efficiently use available information and spend more time thinking about the problem -- analyzing and making sense of it before actually working on details and "doing" the problem. Indeed, in a comparison of an average and an above-average problem-solver, Lester and Garofalo (1987) found that although both students persisted in their attempts to solve the problem, the above-average student monitored her activities, "sat and thought" about the problem before actually attempting to solve it, exhibited confidence in her actions, and checked her answer by estimating. Rather than attempting different strategies, the average student viewed problem-solving as performing a series of computations and exhibited no on-going monitoring or self-regulatory behaviors.

Kilpatrick (1987) further elucidates the issue of strategies and skills in problem-solving behavior. He asserts that the information given explicitly in a problem is usually inadequate for actually solving the problem and that successful problem-solving often requires reformulation and rewording of the problem. Further, he believes students who have solved a problem incompletely or incorrectly should examine their work to see if formulating it in a different way may lead to a better solution.

Peterson (1988) proposes two other dimensions to an analysis of classroom processes that facilitate higher-order math thinking in addition to the teacher's fostering ALB by offering less help and guidance and not encouraging dependence. These are encouraging meaning and understanding versus rote learning learning and teaching high-level executive routines and learning strategies. Peterson, Swing, Stark and Waas (1984) found the ability to monitor one's own understanding to be related to mathematics achievement. Moreover, students who were able to provide a good explanation of what problem or part of the lesson they did not understand had higher scores on a math achievement test. This research yielded other intriguing results. The following variables were significantly related to students' ability to provide a good explanation for their lack of understanding: use of specific cognitive strategies, and checking over their work or checking with the teacher's answer. Additionally, students' provision of a good explanation for their lack of understanding was significantly related to their attitude toward math. General strategy usage was found to be negatively related related to achievement while use of specific cognitive trategies was positively related to achievement. These results lend further support to the importance of self-regulatory and metacognitive strategies for successful problem-solving. Peterson concluded that "a lack of knowledge of cognitive strategies and metacognitive processes may be limiting students' potential for math learning and particularly for higher-order math learning" (p. 14).

Classroom Processes

Leinhardt and Putnam's work (1986) has helped researchers focus on the classroom processes that may contribute to learning in the math classroom. They describe a model learner as one who has a variety of capabilities and the kinds of competencies a student should possess in order to learn math in the classroom of a effective teacher. While "effective" may be the operative word here, their work elucidates the behaviors and strategies that may be important for students in the context of a math lesson. This will be a brief summary of these capabilities in order to relate this important research to the strategies used in the "during a math lesson" category for the questionnaire used in the present research.

The first capability, the action system, assists the student in appropriate school behavior, such as in the recognition of behaviors and situations that are routinized, and the ability to access particular actions in response to particular cues through the use of schemas. The lesson parser enables students to recognize and anticipate the varying components of a math lesson, while the information gatherer allows the student to assimilate information from a lesson and "attach it or distinguish it from other existing knowledge" (p.15). This capability is defined as the students's ability to induce the critical features of a lesson and ignore inconsistent or irrelevant features; the ability to select and focus skills is considered extremely important. The knowledge generator is related to the above competency by means of the select and focus skills. It is the ability of the student to seek out new knowledge and is hypothesized to include a motivational component.

The relationship between this knowledge generator competency and routine and non-routine problems can be described succinctly by reference to the following quote: "... students must be able to discriminate between 'regular' subtraction problems and those with unique features that require the minuend to be rewritten in a way that permits the familiar procedures to be used" (Leinhardt & Putnam, 1986, p.19). The final capability, the evaluator, is important for comprehension monitoring and appears to be strongly related to self-regulation strategies.

Tittle and Hecht (1988) used the literature on problem-solving literature, including the metacognitive and self-regulation research as well as Leinhardt and Putnam's findings, for items in the Math Assessment Project Questionnaire. In the development of their questionnaire, no teachers were consulted regarding autonomous learning behavior or their perceptions of the strategies or behaviors used by good problem-solvers.

Attitudes Toward Mathematics

There is a long history of research on the relationship between gender and attitudes toward mathematics. Carey

(1958), in what has become classic research, found attitudes toward math to be strongly related to performance and found that females both performed less well in math and exhibited poorer attitudes toward the subject. In her experimental study, she used a brief intervention using informal discussion groups to focus on factors involved in problem-solving success, such as the relationship between problem-solving success and problem-solving attitude and encouraged students to examine their own attitudes toward problem-solving. For this sample of first-year college students, she found that for females in the experimental group, there was both an improvement in attitude and performance, however, females did not show a greater attitude change than did males. Carey defined attitude toward math quite broadly, basically as liking or disliking problem-solving and admitted that this was not distinguished from other motivational variables. Since Carey's original research, many studies have found attitudes toward math to be positively related to math achievement (e.g., Hilton & Berglund, 1974; Boswell, 1985; Armstrong, 1985; Ethington & Wolfle, 1988).

A clearer understanding of gender differences in math attitudes was made possible by the development of the Fennema-Sherman Mathematics Attitudes Scales (1976). This instrument contains eight subscales measuring different attitudes. These subscales are: Effectance Motivation in

Math Learning, Math Anxiety, Perceived Usefulness of Math, Confidence in Learning Math, Perception of Math as a Male Domain, and Teacher, Mother and Father's Perceived Attitudes Toward One as a Learner of Math.

A series of studies was conducted using these scales and although not all studies found consistent differences, a pattern of gender differences in math attitudes has indeed emerged. Differences in attitudes favoring males have been found in Usefulness (Sherman, 1976; Sherman, 1979; Fennema & Sherman, 1977; Sherman, 1982), Perception of Math as a Male Domain (Fennema & Sherman, 1977; Sherman, 1979; Sherman, 1982), Confidence in Learning Math (Sherman, 1979; Sherman, 1980; Sherman, 1981) and overall attitudes toward Math (Sherman, 1980; Sherman, 1983).

The attitude of interest for the proposed research was Confidence in Learning Math since the most recent research finds this to be an important variable in females' math achievement (Fox, Brody & Tobin, 1985; Lester & Garofalo, 1987; Garofalo & Lester, 1982; Lantz, 1985; Wise, 1985). Since both Usefulness and Perception of Math as a Male Domain are variables that may not be as amenable to change as Confidence (since confidence may increase when behaviors are altered that may help females to excel in problem-solving), the former attitudes were not of interest to the present research. The relationship between Confidence and math achievement is important since increased success at problem-solving should result in increased confidence, which may in turn enhance problem-solving success. Thus, it is imperative that this attitude be examined in research that investigates possible factors contributing to gender differences in math achievement, particularly when specific behaviors may be identified to help poor problem-solvers increase their achievement in this area.

Summary of the Literature

This literature review has focused on several main areas of research examining gender-related differences in mathematics performance, mathematics course-taking behavior and its relationship to math achievement, and models put forth to understand the relationship between gender and a variety of math achievement and study behaviors. There is a long history of research in gender-related differences in mathematics performance (e.g., Carey, 1958; Hilton & Berglund, 1974; Sherman, 1977; Wise, 1985). Although consideration of amount of math studied may decrease the gender differences, these differences tend to persist, particularly for all levels of problem-solving and in the most advanced math courses (Sherman, 1981; Armstrong, 1985). Additionally, gender differences are seen both in mathematics performance in the classroom and on standardized math tests.

Several models have been conceptualized and tested to examine variables leading to these gender differences both in achievement and willingness to continue the study of math. While many of these variables are functional for an understanding of the dynamics underlying these differences, few are able to suggest methods for change in the classroom for mathematics educators.

The Autonomous Learning Behavior Model conceptualized by Fennema and Peterson (1985) is a useful vehicle for the investigation of gender-related differences in mathematics performance. Their description of autonomous learning behaviors and of possible gender differences in approaches to "doing" math suggest that self-regulatory and metacognitive strategies may be useful methods of defining ALB. Indeed, research in self-regulation indicates that the use of self-regulation techniques positively affects academic achievement (e.g., Schunk, 1984; Zimmerman & Pons, 1986). Furthermore, research in metacognition and problem-solving suggests that students' knowledge and use of metacognitive strategies differentiate good from poor problem-solvers, particularly on high-level or unfamiliar problems (e.g., Lester & Garofalo, 1987; Peterson, 1988).

Attitudes toward mathematics have been consistently found to be related to mathematics performance, with females exhibiting poorer attitudes than do males (e.g., Sherman, 1980; Sherman, 1983; Ethington & Wolfle, 1988). Specifically, three attitudes continue to differentiate females and males -- usefulness of math, perception of math as a male domain, and confidence in learning math. For the present research, confidence in learning math was a most important variable, since it is most likely to be affected by changes in achievement when specific characteristics of good problem-solving strategies are identified and taught.

Thus far, no research has investigated possible gender differences in ALB. Moreover, although findings from research in metacognition has suggested certain strategies and approaches to problem-solving to be significantly related to success in this area, no studies have yet attempted to obtain teacher-defined characteristics of ALB and related these to students' performance in math.

Recent research suggests that classroom and standardized test environments may differentially affect math performance for females and males (Wentzel, 1988). Additionally, Tittle (1988) found that student responses to metacognitive statements on the Math Assessment Questionnaire varied as a function of the type of problem presented. This finding suggests the complexity of methodological considerations in research designed to uncover variables which predict math performance and perhaps, hints at possible sources of the contradictory findings reported by researchers in the field. The interaction between the type of math problem (as opposed to math level) and problem-solving behaviors has been ignored to date. The present research contributes to filling this methodological and theoretical gap by investigating the relationship between responses on the ALB questionnaire and performance on both routine and non-routine word problems.

This research was an attempt to clarify these important issues. Drawing on teachers' working knowledge as well as the cognitive and metacognitive components of problem-solving as defined in the literature, a student self-report measure of ALB was developed. Other independent variables in the study were gender and confidence in learning math. These variables were used in regression analyses to predict the dependent variables routine and non-routine math word problem scores and standardized math test score.

Hypotheses

The hypotheses tested in the present research are listed below.

1. Autonomous learning behavior predicts achievement for each of the dependent variables significantly more than do either gender or confidence.

2. Gender does not significantly add to each prediction beyond ALB and confidence.

3. Males exhibit the characteristics of ALB to a significantly greater extent than do females.

4. ALB is positively correlated with confidence in learning mathematics.

5. The interaction of ALB and Confidence predicts each dependent variable significantly greater than does any other interaction term.

6. Gender is a more important predictor for non-routine problems than for routine problems.

7. Gender is a more important predictor for standardized math test scores than for routine word problems.

8. The beta weights for each of the independent variables (gender, ALB and confidence in learning math) vary for the three dependent variables (scores on routine and non-routine word problems and standardized math tests).

III. METHOD

Overview

This study was concerned with the relationship of routine and non-routine math word problem and standardized math test scores to gender, students' self-ratings on behaviors and strategies of autonomous learning behavior, and students' confidence in learning math. In order to develop an ALB self-rating measure reflective of the practical experiences and observations of math instructors as well as theory and previous research, research on teachers' definitions of ALB characteristics was undertaken. A questionnaire was constructed based on these data and the literature on problem-solving strategies. Scores on this measure, along with gender and confidence in learning math, were related to the dependent variables described above.

Thus, this study was conducted in two phases: Instrument Development and Data Collection.

Phase I: Instrument Development

Phase I of this study entailed the construction of an instrument to measure student self-ratings on teacher and literature defined ALB characteristics and the construction of a 12 item routine and non-routine math word problem task.

I. Autonomous Math Learning Behavior Questionnaire

A. Pilot Study: Teacher-Generated ALB Characteristics

A pilot study was conducted in an effort to obtain teacher-generated characteristics of ALB. While research has identified many behaviors in which good problem-solvers appear to engage, one of the concerns of this research was to be able to identify characteristics of good problem-solvers and autonomous math learners grounded in teachers' working knowledge. An open-ended questionnaire was administered to 10 seventh and eighth grade math certified teachers in four different suburban New Jersey school districts. These teachers were asked to think of a student whom they considered to be a good problem-solver and an autonomous math learner and list specific characteristics and behaviors they had seen exhibited by this student. The form and directions provided for this task appear in Appendix A.

A total of 37 ALB strategies and behaviors were listed by these teachers. All behaviors listed by teachers were included in the construction of the ALB questionnaire.

B. Construction of ALB Questionnaire

1. Teacher-Generated Definitions of ALB. The 37 teacher-generated ALB strategies and behaviors identified in the pilot study were compared to the items in the Math Assessment Project Questionnaire (MAPQ) (Tittle & Hecht,

1988). This questionnaire was designed to assess students' awareness of their behaviors in math class and when solving a non-routine word problem. The items included in their measure were gleaned from the research on metacognitive and self-regulatory strategies in the problem-solving literature and the work of Leinhardt and Putnam (1986)on strategies used during math lessons. A factor analysis performed on the original metacognitive, individual problem items found four factors fitting the categories of "before," "during," and "after" solving a non-routine word problem, and a strategies factor. There was also considerable variability in responses to items, suggesting its potential usefulness for this type of research. Consequently, the MAPQ was divided into four sections reflective of the factors. In the original work, Tittle and Hecht presented students with one non-routine math problem at the beginning of the questionnaire in order to provide a context for the students' responses.

Thirteen of the characteristics identified by teachers in the pilot study did in fact reflect those identified in the math metacognition and self-regulation literature and were represented in the original MAPQ. However, 24 behaviors and characteristics generated by the pilot teachers were not included in Tittle and Hecht's questionnaire. These 24 items plus 33 items (which included the 13 teacher-generated items) selected from the MAPQ as reflective of possible ALB behaviors, were integrated into a version of the MAPQ. This version was adapted from the original, as the original was worded in a style to which students responded. This "teacher version" contained the same items, but worded in a fashion to which teachers could respond based on their observations rather than as a self-report by students.

The four factors into which the items were divided, as discussed above, also made up the four sections of the new measure, the ALB measure. A prefix statement introduced each section, with a list of behaviors included beneath this prefix. For the "before" section the prefix read

> "Students have just read a difficult or non-routine word problem. Before beginning to solve it, students who are autonomous math learners are those who:".

Beneath this prefix was a numbered list of strategies or behaviors, such as: 1. "read the problem more than once." The numbered items each complete the sentence, and the prefix is not repeated again for that section. Likewise, the "during" section is introduced by the prefix

> "Students are now working on a difficult or non-routine word problem. Students who are autonomous math learners are those who:".

Again, a numbered list of items followed, each completing the sentence. For the "after" section, the prefix read

> "Students have finished working on a difficult or non-routine word problem. Students who are autonomous math learners are those who:".

The "during a math lesson" section was introduced by the prefix

> "The students are in class during a math lesson about difficult word problems. Students who are autonomous math learners are those who:".

This ALB measure was administered to 25 math teachers (see below) and appears in Appendix B.

2. Procedure: Autonomous Learning Behavior Questionnaire. Twenty-five math teachers participated in this phase of the study. The teachers were recruited from eight schools - three private and five public- in New York City and suburban northern New Jersey. In each case, the investigator contacted the Chair of the athematics department, who then made contact with individual teachers and handed them the ALB measure. Virtually all teachers meeting the requirements did agree to complete the form. In order to participate, the teachers were required to meet the following three criteria: 1) possess a license to teach mathematics; 2) have a minimum of three years' experience teaching junior high school math; and 3)

presently be teaching mathematics.

Each participating teacher was instructed to indicate for each item whether the behavior was characteristic of ALB by checking either "no," "maybe," or "yes."

3. Item Selection of Teacher-Generated ALB Questionnaire. Teacher-generated items to which 30% or more of the teachers checked "no" were eliminated from the measure. Since students were going to be asked to respond to items based on a particular non-routine problem that would precede these items, (see below), those items that would be inappropriate to solving that problem were also eliminated. All items selected from the original MAPQ were included in the Student ALB Self-Report measure, for a total of 51 items.

C. Student ALB Self-Report Questionnaire

The student ALB questionnaire contained 51 items describing strategies and behaviors that could be used at three different stages of problem-solving and in the classroom (see Appendix C). The same four sections used in the teacher ALB measure were used in this student ALB measure. In accord with the procedure followed by Tittle and Hecht, a non-routine word problem preceded the presentation of the ALB items. The non-routine problem presented at the beginning of the questionnaire was the same used in the MAPQ. The problem read:

> "Eight pennies are arranged in a row on a table. Every other coin is replaced with a nickel. Then, every third coin is replaced with a dime. Finally, every fourth coin is replaced with a quarter. What is the total value of the coins on the table?"

This problem gave the students a specific stimulus on which to reflect when responding to items regarding strategies/behaviors used before, during and after solving a non-routine problem.

In the Student ALB Self-Report Measure, students were asked to think of themselves at three stages of problem-solving and during math class and indicate if they used the ALB strategies or behaviors selected by the above procedures. The prefix for the "before" section of the Student ALB measure read:

> "Before you began to solve the problem-- what did you do? Try to think of exactly what you did. Circle the answer that best describes what you think you did".

The prefix for the "during" section read

> "As you worked the problem--what did you do? Circle the answer that best describes what you think you did."

For the "after" section, students were instructed thusly:

> "After you finished working the problem-- what did you do? Circle the answer that best describes what you think you did".

For the "during a math lesson" section, the introductory prefix read

> "What happens when you work word problems in your math classroom? Think about when your teacher teaches about word problems. What do you do during your math class? Try to think of exactly what you do and answer NO MAYBE or YES to each statement."

The prefix wording was identical to that used in the MAPQ. Students also responded "no," "maybe," or "yes" to the prior three sections of the scale.

A reliability analysis performed on the data generated from the 122 subjects who participated in Phase II of the study (see below) revealed an alpha coefficient of .72 for the Student ALB Self-Report Questionnaire. An item-to-total score correlation analysis was performed to refine the instrument. Nine items were dropped because they correlated negatively with the overall ALB score. Another five items were eliminated due to insufficient variability. On these five items, 80% or more of the subjects selected the same response option ("no", "maybe" or "yes"). Thus, 37 items remained for further analysis. A reliability analysis performed on the refined measure yielded an alpha of .79.

II. Routine and Non-Routine Math Word Problem-Solving Task

An instrument was designed to measure student achievement on routine and non-routine math word problems. Two steps were taken in the development of this measure.

Step 1. The cooperating junior high school employs two math teachers for each grade level. The school has three levels of math in the eighth grade: advanced (Algebra), intermediate, and basic. A different textbook is used for the advanced students, while the same book is used for the intermediate and basic levels. The investigator met with and interviewed the two eighth grade math teachers and received copies of the two math textbooks used by these teachers. Each teacher provided information regarding the content knowledge shared by students in all three levels and identified nine chapters in the textbooks containing content with which all students would be familiar.

Step 2. Routine word problems were defined as those likely to be encountered by students in their math classes and contain fewer than four steps. Thus, the investigator examined the nine aforementioned chapters for prospective routine word problems included in the body of the textbook. The investigator chose problems from each chapter that tapped the knowledge of different mathematical operations--addition, subtraction, multiplication, division, percentages, fractions and combinations of these operations.

For these routine problems, either the wording or the actual numbers included in the problem were changed so that although the operations required remained routine, these were not the exact problems with which students had previous experience. Eight of these problems were chosen. An example of a routine problem is:

> One of Mr. Kaye's 2 motels has 24 rooms, which rent for $23.50 each. His other motel has 30 rooms, which rent for $26.75 each. When both motels are full, how much money is taken in?

Non-routine problems were defined as those requiring more than three operations, those with extraneous information, or those not represented in the chapters covered in the daily math classes. The content knowledge (algorithms) required to solve the non-routine was the same as those used for the routine problems. Two resources were used for the selection of non-routine problems. The first source consulted was the section titled "extra thinking problems" that appeared at the end of each chapter in the textbooks. Conversations with the two cooperating math teachers had revealed that these problems were not used daily in the classroom. Thus, several of these problems were chosen, although the wording and numbers were changed. Additionally, the "Ideas" section of five recent volumes of the Arithmetic Teacher were examined for non-routine word problems that were appropriate for eighth grade math students. Two problems were chosen from these volumes. Since "hands on" materials and group work was often involved for these problems, fewer were selected from this source than from the "extra thinking" sections of the textbooks. An example of a non-routine problem is:

> A wine vat was only 1/2 full. After 4 empty wine bottles were filled, the wine vat was only 1/4 full. How many bottles could be filled if the wine vat were full?

Eight non-routine problems were represented in the first draft of the problem-solving task.

Although the math problem-solving task was to contain only 12 problems, 16 were included in the original pool in order to allow for the elimination of problems on which teacher-agreement (on ratings of routine or non-routine) could not be reached. Thus, sixteen problems were presented to the math teachers to be rated as routine or non-routine.

The two math teachers were individually given the following directions:

> "Please rate these problems as "routine" or "non-routine" for your eighth grade students. Routine problems would be of the type encountered by your students as part of normal classroom activities. Non-routine problems would be of the type not normally

encountered by your students yet requiring no more math knowledge than the routine."

They were asked to denote routine problems by an "r" and non-routine problems by "nr". The teachers did not discuss their ratings until after they completed them. Agreement was reached on fourteen of the sixteen problems on ratings of routine and non-routine. The teachers disagreed on two problems-- one that the investigator had originally defined as routine and another previously defined as non-routine. One teacher was in agreement with the investigator's original rating and the other teacher rated the problems in the opposite direction. Additionally, one routine problem was rated as too simple for their students, and one non-routine was rated as too difficult and confusing for this particular sample of students. These two problems were also eliminated. Thus, the final problem-solving task contained six routine and six non-routine word problems. The math word problem-solving task is presented in Appendix D.

III. Pilot Study: ALB Questionnaire and Word Problems

A small pilot study was conducted to determine two aspects of the instruments developed for this research. First, the investigator wanted to verify that students at the eighth grade level could easily comprehend what was required of them on the ALB questionnaire and if the items were clearly worded. Additionally, it was necessary to determine if variability was evident on responses to items on the ALB questionnaire, as well as on answers to the word problems included in the problem-solving task.

Five eighth grade students from a different school district in the same New Jersey county were used in this pilot study. Subjects reported that the ALB questionnaire was easily understood and that they encountered no difficulties in understanding what was required of them. Moreover, there was considerable variability on responses to the ALB items. Considerable variability was also found in the correctness of answers to the routine and non-routine word problems.

Phase II: Gender, ALB, Confidence in Learning Math and Math Achievement

The second phase of this research consisted of data collection which assessed the relationship of scores on routine and non-routine word problems and standardized math tests to ALB, gender and Confidence in learning math.

General description of the school system and population

The area from which the subjects were obtained is an upper-middle class community in suburban northern New Jersey. The school system is one that has become identified with excellence in its academic programs and is progressive in its innovative approaches. The team approach used in the junior high school affords each student the opportunity to be guided in curricular and placement decisions by teachers who work together to focus on the needs and concerns of individual students. Furthermore, the superintendent is sensitive to the affective component of education, and considers this an important aspect of the learning process.

During separate conversations with the superintendent, junior high school principal, and math teachers, it became evident that parents are quite involved in the school system and demand a high quality of education for their children. This is a school system in which a budget has not been voted down in 30 years. The superintendent, principal, and teachers were all supportive of this research and the Board of Education required that a report of the findings be presented to its members upon completion of the project.

Subjects and Recruitment

The investigator initially contacted the superintendent of the school system, who presented the proposal to the Board of Education for approval. Once approved, the principal and the investigator worked jointly on a letter and permission slip that was distributed to all 152 eighth grade students by their mathematics teacher. Of these 152 students, 30 declined to participate or did not return the permission slip. Thus, the final sample consisted of 122 subjects-- 70 females and 52 males.

The subjects represented all levels of math achievement, with students tracked in specific math classes according to this achievement. The school had three levels of math for the eighth grade. These were advanced (Algebra), intermediate, and basic. The investigator was informed that the pace was slower for the basic group and that some chapters were omitted for these students. One math teacher commented that what separated the basic level students from those in the intermediate course was often their reading ability.

Procedure

Subjects completed two questionnaires: the ALB measure, and a short questionnaire measuring their confidence in learning mathematics. Additionally, subjects solved 12 math word problems-6 routine and 6 non-routine, as described in the previous section.

Data collection was conducted on two days in two consecutive weeks for each of the two teachers' classes, for a total of four days. This was done to avoid any possible confounding effects between the questionnaires and the word problem-solving task. All subjects completed the problem-solving task on Day 1. This task was presented first in order to avoid the possibility that the ALB questionnaire itself would encourage the use of problem-solving strategies not previously employed by the students. The Confidence in Learning Math scale and the ALB scale were both completed in the same session on Day 2. The Confidence scale was completed prior to the ALB scale to avoid the possibility that solving the problem presented at the beginning of the ALB questionnaire would affect students' confidence in such a way as to affect responses on the Confidence scale.

The principal and math teachers determined this research to be a worthwhile experience for both students and teachers. Thus, data collection for both days was conducted during the students' scheduled math period.

Day 1: Math word problem-solving task. On the first day of data collection, students completed the word problem-solving task. Students were advised that their scores on the task would not in any way affect their course grades and that their teachers would not be advised of their scores. Moreover, students were reminded of the protection of their anonymity and that their participation was helping the investigator in her research. Although the period was 40 minutes in duration, most students completed the task in 20-30 minutes. Upon completion of the task, teachers either administered math seatwork or "thinking skills" activities to the students.

Day 2: Questionnaires. On the second day of data collection, exactly one week from the first day for each class, students first completed the Confidence in Learning math scale and then were administered the ALB scale.

Confidence in Learning Mathematics Questionnaire. Confidence in learning math was assessed by a subscale of the Fennema-Sherman Mathematics' Attitudes Scales (Fennema & Sherman, 1976; see Appendix E). The original scale contains eight domain specific, Likert scales developed to assess attitudes related to the learning of mathematics. Although an overall "attitudes toward math" score may be obtained, the subscales are often administered and scored separately. The present study utilized the Confidence in Learning Mathematics subscale only.

Fennema and Sherman describe the scale thusly: "the Confidence in Learning Mathematics Scale is intended to measure confidence in one's ability to learn and to perform well on mathematical tasks. The dimension ranges from distinct lack of confidence to definite confidence. The scale is not intended to measure anxiety and/or mental confusion, interest, enjoyment or zest in problem-solving" (p.4). The scale consists of 12 items and students indicate on a Likert-type scale their degree of agreement with each statement ranging from strongly agree to strongly disagree. Six items are positively weighted and six are negatively weighted. For example, two items read: "I think I could handle more difficult mathematics," and "For some reason, even though I study, math seems unusually hard for me."

Split-half reliability for the scale is .93.

Although the original scale was developed using 9-12 grade students, communication with Fennema (1/18/89), revealed that the scales have been successfully used with junior high school samples with no changes. The scale, therefore, was judged appropriate for use with eighth grade subjects.

<u>Autonomous Learning Behavior Questionnaire</u>. The development of the ALB questionnaire has been described above. Students are initially required to solve a non-routine word problem. The remainder of the measure is comprised of four parts. Part I required students to think of their thoughts and behaviors before beginning to solve the non-routine problem presented at the beginning of the questionnaire; Part II required students to think of their behavior while working on the problem; Part III required students to recall their thoughts and behaviors when they were finished working on the problem; and Part IV required students to imagine themselves sitting in class during a math lesson. Immediately following each section, a list of items followed that described different behaviors or strategies in which students may or may not engage at the different stages of problem-solving and in the math classroom.

Scoring for responses to individual items was as follows. For items that were positively weighted, NO = 1, MAYBE = 2, YES = 3. For items negatively weighted, NO = 3, MAYBE = 2, YES = 1. Total scores were obtained by adding together the numbers assigned to the individual items, such that the highest possible score was 101.

Standardized Mathematics Test Scores

The cooperating school provided the students' seventh grade scores on the math section of the Iowa Test of Basic Skills. For each student an overall score was obtained in addition to a score for each sub-test-- concepts, problems and computation. These scores were expressed in national percentile ranks. No student's test scores were obtained without the written consent of a parent/guardian.

Data Analysis

The relationship of scores on routine and non-routine word problems and standardized math test scores to ALB, gender and Confidence in learning math was analyzed using multiple regression analyses. The dependent variables used in the analyses were expressed in the following manner:

Y_1= Standardized Math Test Scores

Y_2= Scores on Routine Math Word Problems

Y_3= Scores on Non-Routine Math Word Problems

Independent variables were expressed in the following manner:

X_1= Gender

X_2= Autonomous Learning Behavior

X_3= Confidence in Learning Mathematics

Each dependent variable was regressed on the three independent variables and the interaction terms by means of the following equations.

For the dependent variable "standardized math test scores", the equation tested was:

$$Y_1 = a_1 + b_{11}X_1 + b_{12}X_2 + b_{13}X_3 + b_{14}X_1X_2 + b_{15}X_1X_3 + b_{16}X_2X_3 + b_{17}X_1X_2X_3 + e_1$$

For the dependent variable "routine math word problems", the equation tested was:

$$Y_2 = a_2 + b_{21}X_1 + b_{22}X_2 + b_{23}X_3 + b_{24}X_1X_2 + b_{25}X_1X_3 + b_{26}X_2X_3 + b_{27}X_1X2X3 + e_2$$

For the dependent variable "non-routine math word problems", the equation tested was:

$$Y_3 = a_3 + b_{31}X_1 + b_{32}X_2 + b_{33}X_3 + b_{34}X_1X_2 + b_{35}X_1X_3 + b_{36}X_2X_3 + b_{37}X_1X_2X_3 + e_3$$

IV. RESULTS

Stage I Analyses

Preliminary analyses were conducted to examine the relationship of math achievement, ALB and Confidence in learning math to gender. Two-tailed *T*-tests were performed to assess the relationship between these variables using all sub-tests, as well as the overall math score, on the Iowa Test of Basic Skills, the routine and non-routine word problem scores and scores on the ALB Student Self-Report and Confidence in Learning Math Questionnaires. All scores for the math achievemant measures were expressed in terms of percentages, with the Iowa scores representing national percentile ranks. The number of subjects differed for some of the achievement measures since not all scores were available for all subjects. The results of these analyses are presented in Table 1.

No gender differences were found on any of the math achievement measures or on the ALB questionnaire. The analysis performed on gender for the Confidence in Learning Math measure did reveal significantly higher confidence scores for males (M= 49.3) than for females (M= 45.6; p<.01). It should be noted, however, that although the *t*-test for Confidence was significant, this result may be due to the fact that eight *t*-tests were performed. A more conservative approach, based on the Bonferroni inequality,

Table 1

Means, standard deviations and results of t-tests performed on gender for math achievement measures, confidence in learning math and ALB scores

Variable	No. cases	Mean	S.D.	T	2-Tail Prob.
IOWA MATH CONCEPTS					
MALES	51	78.7	19.2	0.17	NS
FEMALES	69	78.1	18.9		
IOWA MATH PROBLEMS					
MALES	51	73.5	19.6	-0.03	NS
FEMALES	66	73.6	19.9		
IOWA MATH COMPUTATION					
MALES	51	76.5	17.2	-1.45	NS
FEMALES	70	81.2	17.8		
OVERALL IOWA					
MALES	52	79.2	16.7	-0.47	NS
FEMALES	68	80.6	17.2		
ROUTINE PROBLEMS					
MALES	52	74.7	23.3	1.13	NS
FEMALES	70	70.0	22.1		
NON-ROUTINE PROBLEMS					
MALES	52	66.4	26.0	0.23	NS
FEMALES	70	65.3	26.3		
CONFIDENCE IN MATH					
MALES	52	49.3	7.8	2.68	<.01
FEMALES	70	45.6	7.5		
ALB SCORE					
MALES	51	80.7	10.7	-1.37	NS
FEMALES	70	83.1	8.3		

is to perform each test at the /8 level of significance. If = .05/8 = .006, then the gender difference in Confidence in learning math cannot be considered significant.

Pearson correlation analyses were conducted to determine the intercorrelations of the variables, including the interaction terms, used in the study. Table 2 presents the results of these analyses. The intercorrelations among the math achievement measures were all highly significant. For routine and non-routine word problems, r=.44 ($p<.01$); for routine problems and the standardized math score, r=.64 ($p<.01$); for non-routine problems and the overall standardized score, r=.59 ($p<.01$).

As would be expected, the interaction terms were all highly correlated with the individual variables from which they were derived. For example, for the correlation of Confidence and ALB*Confidence, r=.81 ($p<.01$). All other correlations of the interaction terms with the individual variables revealed similar results when that particular variable was included in the interaction term. The only significant correlation of an interaction term with an individual variable not included in that term was between ALB*Gender and Confidence in learning math (r=-.22, $p<.01$).

Significant correlations between individual variables were found for ALB score and overall standardized math test score (r=-.19, $p<.04$) and Confidence in learning math and gender (r=.24, $p<.01$).

Table 2

Intercorrelations of Independent and Dependent Variables

	R	NR	IWA	GDR	C	ALB	ALBC	ALBG
R	1.0	.44 (122) P<.01	.64 (120) P<.01					
NR		1.0	.59 (120) P<.01					
GDR	-.10 (122) NS	-.02 (122) NS	.04 (120) NS	1.0	-.24 (122) P<.01	.12 (121) NS	-.13 (121) NS	.95 (121) P<.01
C	.13 (122) NS	.15 (122) NS	.11 (120) NS		1.0	-.009 (121) NS	.81 (121) P<.01	-.22 (121) P<.01
ALB	-.02 (121) NS	-.08 (121) NS	-.19 (119) P=.04			1.0	.57 (121) P=.01	.42 (121) P<.01
ALBC	.10 (121) NS	.07 (121) NS	-.02 (119) NS				1.0	.05 (121) NS
ALBG	-.11 (121) NS	-.05 (121) NS	-.04 (119) NS					1.0
GDC	-.08 (122) NS	.05 (122) NS	.07 (120) NS	.86 (122) P<.01	.27 (122) P<.01	.11 (121) NS	.28 (121) P<.01	.81 (121) P<.01

(Coefficient/ (Cases)/ 2-Tailed Significance-NS=Not significant)

R= Routine word problem score
NR= Non-routine word problem score
IWA= Iowa standardized math test score
GDR= Gender
C= Confidence in learning math
ALB= ALB score
ALBC= ALB*Confidence
ALBG= ALB*Gender
GDC= Gender*Confidence

Stage II Analyses- Testing the Hypotheses

Hypothesis #1. Autonomous learning behavior predicts achievement for each dependent variable significantly more than do either gender or confidence.

This hypothesis was tested for each dependent variable using multiple regression analyses. Table 3 depicts the results of these analyses. The columns in the table represent the multiple correlations showing the contribution of ALB, Confidence in learning math and Gender in the regression analyses. The first variable entered into each equation was ALB, and the correlation presented is the simple correlation of ALB with each dependent variable. The coefficient presented for each variable beneath ALB is the multiple correlation of the new variable and the preceding variable(s) with the dependent variables.

Hypothesis #1 was not supported when the dependent variable was routine math problem score. This result is seen in Table 3. Autonomous learning behavior was not significantly correlated with this dependent variable ($r=.02$) and thus by itself, was an insignificant predictor. With the addition of the next variable, Confidence in learning math, the multiple R is increased to .13, an insignificant increment of .11. The next variable to be entered into the regression equation was Gender ($R=.14$),

Table 3

Multiple Correlations Showing the Contribution of ALB, Confidence in Learning Math and Gender in the Regression Analyses

	Dependent variables		
	Routine	Non-routine	Iowa
ALB	r= .02	r= .08	r=-.19*
Confidence	R= .13	R= .17	R= .22
Gender	R= .14	R= .17	R= .24
Gender* Confidence	R= .30***	R= .17	R= .30*

* = $p < .04$

** = $p < .03$

*** = $p < .02$

resulting in an insignificant increment of .01. When the interaction term Gender*Confidence was entered into the equation, the resulting multiple R was .30, a significant increment of .16. No other variables or interaction terms significantly added to the prediction before or after the inclusion of this interaction term. However, these variables together explained only 9% of the variance in routine word problem score.

Hypothesis #1 was also not supported when the dependent variable was non-routine word problem score. This result can also been seen in Table 3. The simple correlation of ALB and non-routine word problem score was insignificant ($r=.08$), therefore autonomous learning behavior was not a predictor of non-routine problem score. When Confidence in learning math was entered into the equation, the multiple R rose to .17, an insignificant increment of .09. Moreover, as can be seen in the table, the addition of Gender and the interaction term Confidence*Gender reveals no rise at all in prediction and a final multiple R of .17. Thus, non-routine word problem score could not be predicted from these independent variables.

In the case of the dependent variable standardized math test score, Hypothesis #1 was supported. This result can be seen in Table 3. The simple correlation of ALB with the Iowa math test score was significant ($r= -.19$, $p<.04$). Thus, autonomous learning behavior is a significant, although negative, predictor of standardized math test score. Additionally, when Confidence in learning math was added to the equation, the multiple R increased to .22, an insignificant increment of .03. When Gender was entered into the equation the multiple R rose to .24, an insignificant increment of .02. Therefore, ALB does indeed predict standardized math test score significantly more than did either Confidence in learning math or Gender. However, the inclusion of the interaction term Gender*Confidence resulted in a rise in the multiple R to .30, a significant increment of .06. Thus, although neither variable alone could significantly add to the prediction, the interaction of these two variables was important. No other variables or interaction terms added significantly in this prediction. As in the case of the dependent variable routine word problem score, the variance accounted for by these variables was only 9%. ALB alone explained only 4% of the variance in the standardized math score. The finding that the interaction of gender and confidence added significantly to the prediction of the dependent variables routine word problem score and standardized math test score, was unexpected.

The regression equation for the prediction of routine word problem score from Gender, ALB, Confidence in learning math and the Gender*Confidence interaction was as follows:

$$Y_2 = -53 + 72.9(\text{Gender}) + -.05(\text{ALB}) +$$
$$2.8(\text{Confidence}) +$$
$$- 1.59(\text{Confidence*Gender})$$

If a mean ALB score of 81 is substituted for ALB and the equation evaluated for females (G=2), the following equation results:

$$Y_2 = 89 - .4(C)$$

If a mean ALB score of 81 is substituted for ALB and the equation evaluated for males (G=1), the following equation results:

$$Y_2 = 16 + 1.21(C)$$

Figure 6 presents the graph of these equations. The regression lines show that for males, higher routine word problem scores are related to higher Confidence in learning math. For females an inverse relationship exists. High routine problem scores are related to lower Confidence scores, although at the mean Confidence score of 47, the routine problem scores are almost identical.

The significant two-way interaction term Confidence*Gender was also found in the prediction of the standardized math test score. The regression equation for

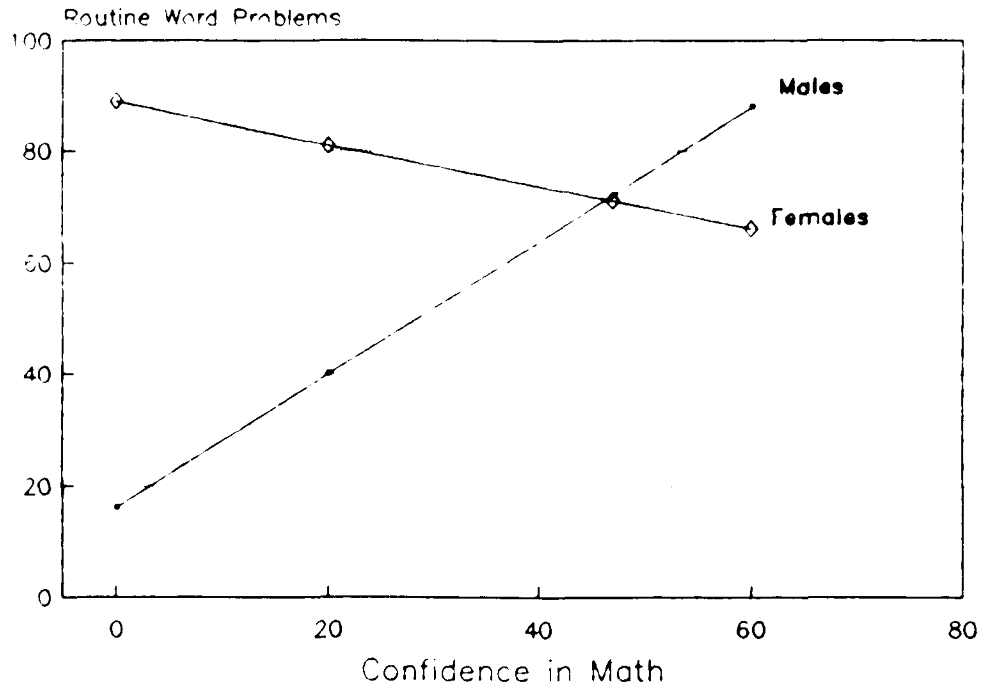


Figure 6
Regression lines for females and males of the relationship between confidence in learning math and routine word problem score when considering ALB

the prediction of the standardized math score from Gender, ALB, Confidence and the Gender*Confidence interaction was as follows:

$$Y_1 = 32 + 41.8(\text{Gender}) + -.38(\text{ALB}) + 1.52(\text{Confidence}) + -.80(\text{Confidence*Gender})$$

If the mean ALB score of 81 is substituted for ALB, and the equation evaluated for females (G=2), the following equation results:

$$Y_1 = 85 - .08(C)$$

Similarly, for males (G=1), the regression equation is:

$$Y_1 = 43 + .72(C)$$

Figure 7 presents the graph of these regression equations.

The regression line in the prediction of the Iowa score shows that for males, as in the case of the routine word problem score, higher standardized scores are related to higher Confidence in learning math scores. For females, the inverse relationship is not as strong as that for the routine problem score. That is, the relationship between Confidence in learning math and the Iowa score is relatively weak. Regardless of the Confidence in math score, the standardized math score for females remains in the range of 80 to 85.

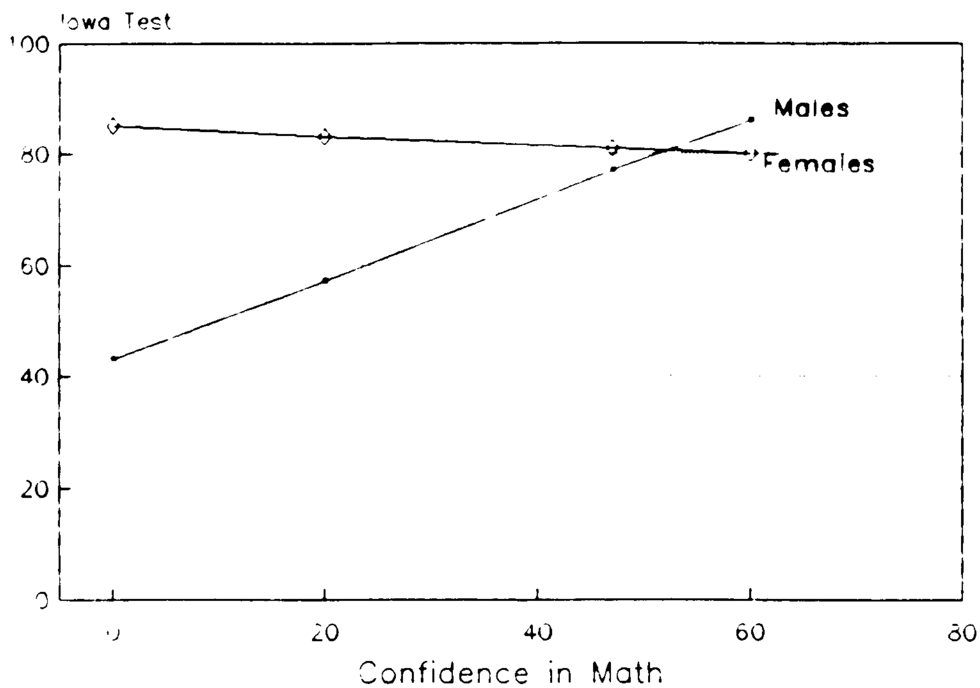


Figure 7

Regression lines for females and males of the relationship between confidence in learning math and standardized math test score when considering ALB

Hypothesis #2. Gender does not significantly add to each prediction beyond ALB and Confidence.

Gender as an individual variable did not significantly add to the prediction of any dependent variable. This result is shown in Table 3. For each dependent variable the addition of Gender into the regression equation resulted in an insignificant increase in the multiple R. In the prediction of the routine word problem score the increase in the multiple R from .13 to .14 was insignificant. In the prediction of the non-routine word problem score there was no increase at all in the multiple R with the addition of Gender into the equation. In the prediction of the Iowa standardized math score, the rise in the multiple R from .22 to .24 with the inclusion of Gender, was insignificant. However, as presented above and depicted in Figures 6 and 7 gender, in combination with Confidence in learning math, did add significantly to the prediction of the dependent variables routine word problem score and standardized math test score.

Hypothesis #3. Males exhibit the characteristics of ALB to a greater extent than do females.

This hypothesis was tested by performing a *t*-test analysis on the ALB scores of females and males. The mean ALB score for females was 83.1, while the mean ALB score for males was 80.7, an insignificant difference. Thus, hypothesis #3 was not supported by these data. The results of this analysis are presented in Table 1.

<u>Hypothesis #4</u>. ALB is positively correlated with Confidence in learning mathematics.

The Pearson correlation analysis performed on the variables ALB and Confidence in learning math yielded a coefficient near zero (r= -.009), an insignificant value. Thus, this hypothesis was not supported. The results of this analysis appear in Table 2.

<u>Hypothesis #5</u>. The interaction of ALB and Confidence in learning math predicts each of the dependent variables significantly greater than do any other interaction terms.

This hypothesis was tested by performing a multiple regression analysis on each dependent variable. In the prediction of each dependent variable, the interaction term ALB*Confidence was entered into the equation immediately following the individual independent variables. In the prediction of the routine word problem score, the inclusion of the term ALB*Confidence did not increase the multiple R from the previous variable Gender. Further, the addition of another interaction term Gender*Confidence did increase the prediction such that the rise in the multiple R from .14 to .31 was significant. For the dependent variable non-routine word problem score, none of the individual independent variables nor any interaction term was successful in the prediction. For the dependent variable standardized math test score, the addition of the interaction term

ALB*Confidence into the regression equation did not result in an increase in the multiple R over the previous individual variable, gender. Indeed, the multiple R remained the same. Moreover, the addition of the interaction term Confidence*Gender did add significantly to the prediction. The multiple R rose from .24 to .30, a significant increment of .06. Thus, hypothesis #5 was not supported for any dependent variable.

Hypothesis #6. Gender is a more important predictor for non-routine math problems than for routine problems.

This hypothesis was tested by Pearson correlation analyses. The coefficients yielded in each analysis revealed insignificant relationships of routine word problem score to gender ($r=-.10$); and non-routine word problem score to gender ($r=-.02$). The results of the Pearson correlation analyses appear in Table 2.

Hypothesis #7. Gender is a more important predictor for standardized math test scores than for routine word problems.

This hypothesis was tested in the same manner as hypothesis #6. In the case of the standardized math test score, the correlation coefficient derived form a Pearson correlation analysis revealed an insignificant relationship of standardized math test score to gender ($r=.04$). As reported above, the coefficient for routine math word problem score and gender, was also insignificant.

Hypothesis #8. The beta weights for each of the independent variables vary for the three dependent variables.

This hypothesis was included in the case that the same independent variables predicted the different dependent variables. However, tests of this hypothesis were not required since a different pattern of variables was evident for the significant predictions of routine word problem score and standardized math test score.

Summary of results

Although ALB was included in the prediction of the variable routine math word problem score, it did not make a significant contribution by itself. The addition of the interaction term Confidence*Gender gave the equation its significant predictive power. Still, the variance in routine word problem score accounted for by these variables was only 9%. ALB was significant as a predictor of the standardized math test score, and the prediction was significantly increased by the inclusion of the two-way interaction term Confidence*Gender, although the equation only accounted for 9% of the variance in this variable also.

Gender by itself did not add any significance in the prediction of the dependent variables, but in combination with Confidence was responsible for an increase in the prediction of routine word problem score and standardized math test score.

The interaction term ALB*Confidence was not significant as a predictor of any dependent variable, yet the interaction term Gender*Confidence did add significantly to the prediction of both routine problem score and standardized math score.

V. DISCUSSION

This research developed a measure of autonomous learning behavior (ALB) and use this variable along with Confidence in learning math and Gender in the prediction of routine and non-routine math word problem scores and standardized math test scores. Results suggest that autonomous learning behavior must be more clearly defined before further research using this construct is conducted.

Although ALB was a significant predictor of standardized math test score, it was an inverse relationship and explained only 4% of the variance. The inclusion of the interaction term Gender*Confidence increased the prediction to account only for 9% of the variance in total. While this was a significant finding, the variance accounted for was so little as to be practically insignificant.

In the case of the dependent variable non-routine word problem score, none of the variables alone or in combination with one another, were significant predictors. While every effort was made to identify word problems that would be considered non-routine by consulting with the math teachers of the students in the sample and by examination of the textbook, it is quite possible that these problems were not non-routine in the students' view. However, given the significant prediction of the dependent variable routine math word problems score, this result is somewhat difficult to interpret. If the problems were routine rather than non-routine, then the same variables should have predicted this dependent variable. This was not the case.

Another explanation could be that these problems were indeed non-routine for these students, but the ALB measure used did not tap the essence of strategies and behaviors needed to solve this group of non-routine problems. While a non-routine problem was presented to students before they responded to the ALB measure, it is quite possible that this particular problem was less difficult than the non-routine problems presented in the problem-solving task. Perhaps the level of difficulty is an important variable to consider when using non-routine problems to research achievement in this area. Future research should therefore focus on possible differences in the relationship among different levels of difficulty in non-routine word problems and ALB.

The dependent variable routine word problem score was not significantly predicted by ALB alone, as had been hypothesized. The inclusion of the interaction term Gender*Confidence in learning math did increase the predictive power and resulted in a significant overall prediction. However, as in the case of the dependent variable standardized math test score, these variables accounted for only 9% of the variance in the routine word problem score. As such, this has little practical significance.

The finding that the interaction term Gender*Confidence significantly added to the prediction of both routine word problem score and standardized math test score, was unexpected. Although research has consistently found gender differences in Confidence in learning math to favor males (e.g., Sherman, 1981; Lantz, 1985; Lester & Garofalo, 1987), the present study hypothesized that neither Gender nor Confidence would add to ALB in the prediction of the dependent variables. When examining the results regarding ALB, though, it is not surprising that this occurred. Apparently, the construct ALB was not operationally defined in a way to make gender differences irrelevant. It is quite possible that had ALB been a more successful predictor of the dependent variables, less of an increment would have been added by the Gender*Confidence interaction term. This result is an important one to which researchers should attend. Until ALB is adequately defined and other significant variables are identified, sex, as an independent variable, could continue to be a part of the explanation for gender differences in math performance. Research has shown that a combination of many variables mediate the relationship between gender and math performance (e.g., Casserly & Rock, 1985; Boswell, 1985).

The finding that Confidence in learning math is related to standardized math test scores and routine word problem scores differently for females and males, warrants further discussion. It has been assumed that Confidence in learning math is important in that it may impact on student math achievement. Thus, one approach to increasing math achievement has been to attempt to increase a students' Confidence in learning math. These results indicate that a different explanation may be appropriate. For males in this sample, the higher the math achievement level, the higher the score on the Confidence in learning math measure. There is no way, however, of suggesting the causative relationship of these variables. However, for females Confidence level and achievement level were inversely related. Although an inverse relationship was found for the dependent variable standardized math test score, it was slight and suggests that Confidence may not be an important variable in this prediction when considering ALB. However, for the dependent variable routine word problem score, this relationship was quite pronounced. Past research conclusions have suggested methods to increase females' confidence in their ability to learn and perform well in math. However, one may also conclude that regardless of past achievement, females remain less confident than males in their ability to achieve highly in math.

Gender differences in math achievement have decreased over the past several years, with fewer studies finding significant gender differences in critical areas of math achievement. However, gender differences persist in the highest levels of math study (e.g., de Wolf, 1982; Wise, 1985) and in standardized tests of math achievement such as the Scholastic Aptitude Test (Rosser, 1988; Gallagher, 1989). Indeed, recent research using a gifted sample of high school students revealed a significant gender difference on the SAT-M favoring males, with a mean difference of 59.65 points (Gallagher, 1989). More in-depth analyses revealed a possible time factor operating such that gender differences in performance on the SAT-M may be attributed to the time restrictions placed on students taking the test and that speed of response could be an important variable.

Hyde, Fennema and Lamon (in press) recently reported results of a meta-analysis of gender differences in math performance. They found age trends in gender differences in math achievement to be related to the cognitive level examined by different tests, with problem-solving achievement in the high school and college years revealing moderate gender differences favoring males. This gender difference in problem-solving achievement was not found for the elementary and middle-school grades. Thus, although gender differences in math achievement may be decreasing in some areas, the persistence of gender differences at the highest levels of problem-solving cannot be ignored and should be of the highest priority for research to those interested in gender equity in math achievement.

Fennema and Peterson (1985) build a rationale for ALB by asserting that differential patterns of socialization may allow for the development of greater autonomous learning behavior in males than in females. Autonomous learning behavior, further reinforced and developed in males in the classroom environment, may be particularly important for the math learning process and for optimal performance on math tasks. This was not the case for the subjects in this sample. No gender differences were found for this sample, using the measure of ALB developed for the present research.

Nonetheless, researchers must not abandon autonomous learning behavior as a possible explanation for gender differences in math performance. It is quite possible that the instrument developed for the present study did not fully tap the essence of autonomous learning behavior. The measure contained items tapping cognitive and metacognitive processes, as well as classroom behaviors. Some of the items in the "during the math class" sub-section appeared to best define how an autonomous math learner behaves or learns in the math classroom. Items such as "I help other students" and "I usually ask question of the 'what if' or 'why' type" may be important indicators of the behaviors and metacognitive processes in which autonomous learners may engage in the math classroom. As such, it may be necessary that to adequately define ALB researchers must focus not only on the cognitive and metacognitive processes employed during the actual problem-solving process but also on behaviors and cognitive and metacognitive process used during the learning of math. It may well be that a scale with more items pertaining to in-class behaviors will help to clarify the concept of autonomous learning behavior. The focus, then, would be on the learning of math and the behaviors that precipitate learning rather than on the performance aspect or the processes involved in solving particular math problems.

As is always a possibility when using self-report measures in research, a social desirability effect could have been operating. Subjects may have chosen options they felt were appropriate responses. Given that teacher-definitions of ALB comprised much of the measure, students may be well attuned to teacher expectations for in-class and problem-solving behaviors.

The ALB measure used in the present research may well be a measure of a "careful" worker. Although there was a variety of item types, many fall into a broad category describing a meticulous problem-solver, taking their time and "plodding along." Results revealed that ALB score was a negative predictor of the standardized math score. Given the time factor involved in the standardized testing context, it is likely that meticulous, step-by-step problem-solvers would not do as well as those who skip steps, take chances and/or estimate results.

Finally, it is possible that the particular sample used in this research may have affected the findings. As has been discussed previously, the school system from which the sample was drawn is rare in its community support, resources, and teaching approaches. Hyde et al. (in press) found sample selectivity to be one of the three most powerful predictors of effect size in gender differences in math performance. While the math achievement scores for the subjects in the present research revealed a good deal of variability, the school system itself may be considered select. Thus, it is possible that a ceiling effect was present, particularly considering that the highest possible score was 101 and the average ALB score for this sample was 81. Findings may have been different for a sample drawn from a less selective school system.

Suggestions for future research

It is important for educational psychologists to continue to pursue autonomous learning behavior as an explanation of gender differences in math achievement. It is also important, however, for the research community to focus on the learning process in addition to the actual problem-solving process. In order to understand the relationship between autonomous math learning behaviors and math performance, we must take a closer look at the behaviors in which successful problem-solvers engage during classroom math lessons. It is possible that the autonomy needed for successful math learning is displayed not only in the approach one uses to solve a particular problem, the metacognitive process, but in the approach one uses to learn in a social context. Thus, future research in this area needs to focus on the student as a member of a classroom "community" and observe behaviors of successful problem-solvers directly. By this method, behaviors may be identified that can then be related to subsequent performance on a variety of math tasks. Moreover, it may help to elucidate the learning process if researchers interviewed successful math students regarding the behaviors in which they engage during math class.

In order to develop a more precise measure of ALB, researchers must continue to receive input from math teachers, since their classroom expertise can serve as a springboard to further research in this area. Research in the area of autonomous learning behavior has not had a long history and requires the sometimes long and tedious examination by many researchers before becoming a construct that can be reliably used in math learning research.

Future research also requires careful consideration of definitions of "non-routine" problems. Perhaps looking outside the usual math curriculum to the critical thinking literature, including logic problems, and using these problems in a math context, may be helpful. However, this may lead to difficulties in interpretation due to the confounding effect of verbal ability on math word problem achievement. Thus, future research using more abstract "non-routine" problems may need to covary verbal ability.

Results from this research suggest that further investigation into the relationship between gender and confidence in learning math may be warranted. Although some previous research has found confidence to be an important predictor for females and not for males, the present investigation found the opposite result to be true.

Implications for education

Educators must continually seek to understand the reciprocal processes involved in classroom learning and different performance contexts. Much of the problem-solving literature has focused on the cognitive and metacognitive processes involved in actual problem-solving, whether in the classroom or in the context of achievement testing. While this research is necessary to understand the strategies employed by students when solving problems, this research cannot be undertaken to the exclusion of research on cognitive and metacognitive processes, as well as behaviors, used by students while they are learning new lessons in the math classroom. ALB may relate to the learning of math concepts and solutions by impacting on the coding, interpretation and evaluation of information, along with the behaviors in which students engage during this information processing.

Although the present research was not successful in finding a strong relationship between ALB and math achievement, the theoretical framework and conceptualization of ALB as presented by Fennema and Peterson, merit continued exploration. Once adequately defined, ALB could hold promise as a vehicle by which <u>all</u> students could improve their understanding of math material when initially presented in class and their performance on achievement measures. Specific classroom behaviors may be taught and students could be trained to improve their learning in the math classroom. Additionally, teachers could be trained to recognize these behaviors and strengthen them in their own students. Math instructors must also help students to recognize their own classroom behaviors and the strategies they use in math learning contexts. Further, teachers can assist students in relating these behaviors and strategies to subsequent performance on a variety of math tasks. As math understanding and success become less of a myth to many students, they may be more willing to engage in math learning at the highest levels.

Conclusion

This research was an attempt to identify math autonomous learning behaviors and use ALB along with Confidence in learning math and Gender in the prediction of routine and non-routine word problem scores and standardized math test scores. Findings revealed that while ALB was insignificant alone as a predictor of routine word problem score, the interaction of Gender and Confidence in learning math significantly increased that prediction. ALB was a significant, though negative, predictor of standardized math test scores, and this prediction was also significantly increased with the addition of the Gender*Confidence interaction term. In both cases though, only 9% of the variance in the dependent measures could be explained by these variables.

Confidence in learning math affected the standardized math test score and the routine word problem score differently for females and males. For males, higher Confidence scores were related to higher achievement scores, while for females an inverse relationship was present. That is, the higher the achievement levels, the lower the level of Confidence in math. While these findings were similar for both standardized scores and the routine word problem scores, this relationship was far more pronounced in the case of the routine word problem scores.

It was concluded that while the present study found only minimal support for ALB as it was defined for this research, its theoretical ground and original conceptualization suggest it has potential as an important construct for the educational research community. Future research should concern itself with refining a measure of autonomous learning behavior such that ALB will be a useful variable in studies of math learning and performance in different educational contexts.

Notes

1. This decision was based on a discussion conducted with one of the authors of the MAPQ. Since the items in the MAPQ were drawn from an abundance of research in the area of metacognitive strategies used during problem-solving and in the math classroom, it was decided that regardless of teacher agreement on these items, the supporting literature necessitated their inclusion in the present measure.

Appendix A

Pilot: Teacher Generated ALB Characteristics

For the past few years, mathematics educators have discussed the behaviors found in students who have highly developed skills in mathematics thinking and problem solving. One general idea that has been suggested is Autonomous Learning Behavior (ALB). While an overall definition of ALB may include the idea that students show independence in learning or can function independently in a math learning situation, we want to find out how teachers define this kind of independence in math learning.

Think about a particular student or students whom you consider to be good problem solvers and autonomous math learners. List as many SPECIFIC characteristics as possible that describe their approach to learning math, as well as behaviors you have observed them using while they are solving problems. Please be specific and list as many examples possible. Do not worry if an example seems to be too detailed or trivial. We are interested in <u>all</u> your examples. Also, please do not INFER, but list behaviors you have observed directly or statements made by the students themselves.

____________________	____________________
____________________	____________________
____________________	____________________
____________________	____________________

Appendix B

Teacher ALB Questionnaire

For the past few years, mathematics educators have discussed the behaviors found in students who have highly developed skills in mathematics thinking and problem-solving. One general idea that has been suggested is Autonomous Learning Behavior (ALB). While an overall definition of ALB may include the idea that students show independence in learning or can function independently in a math learning situation, we want to find out how teachers define this kind of independence in math learning.

Think about a particular student or students whom you would consider to be good problem solvers and autonomous math learners. Read the items below and indicate on the scale of "no", "maybe", or "yes" which characteristics fit with your ideas of what an autonomous math learner does.

Part I

Students have just read a difficult or non-routine word problem. Before beginning to solve it, students who are autonomous math learners are those who:

	NO	MAYBE	YES
1. read the problem more than once	___	___	___
2. read the problem slowly	___	___	___
3. think to themselves, "Do I understand what the question is asking me?	___	___	___
4. try to remember if they have worked a problem like this before.	___	___	___
5. try to put the problem into their own words.	___	___	___
6. think about what information they need to solve this problem.	___	___	___
7. look for patterns in the problem	___	___	___
8. ask themselves, "Is there information in this problem that I don't need?	___	___	___
9. write down important information.	___	___	___
10. can estimate results.	___	___	___

Part II

Students are now working on a difficult or non-routine word problem. Students who are autonomous learners are those who:

	NO	MAYBE	YES
1. think about all the steps as they work the problem.	___	___	___
2. keep looking back at the problem after they do a step.	___	___	___
3. stop and rethink a step they have already done.	___	___	___
4. check their work step-by-step as they work the problem.	___	___	___
5. draw a picture or diagram to help understand the problem.	___	___	___
6. label a picture or diagram.	___	___	___
7. immediately picks out the operations needed to do the problem.	___	___	___
8. feel confused and can not decide what to do.	___	___	___
9. don't know how they are doing until they reach the final step.	___	___	___
10. ask the teacher to check each step as they work it.	___	___	___
11. don't get distracted and give total attention to the task at hand.	___	___	___
12. persevere in their attempts.	___	___	___
13. work backwards.	___	___	___
14. work quietly.	___	___	___
15. are eager to get an answer.	___	___	___
16. follow orderly procedures.	___	___	___

	NO	MAYBE	YES
17. can use formulas.	___	___	___
18. can convert measures.	___	___	___
19. have a competitive drive to arrive at the correct solution.	___	___	___

Part III

Student have finished working on a difficult or non-routine word problem. Students who are autonomous math learners are those who:

	NO	MAYBE	YES
1. look back to see if they did the correct procedures.	___	___	___
2. check to see if the calculations they performed were correct.	___	___	___
3. receive satisfaction from correct results.	___	___	___
4. go back and check the work again.	___	___	___
5. look back at the problem to see if the answer makes sense.	___	___	___
6. don't know how they have performed until they get teacher feedback.	___	___	___
7. never check their own work.	___	___	___
8. think about a different way to solve the problem.	___	___	___

Part IV

The students are in class during a math lesson about difficult word problems. Students who are autonomous math learners are those who:

	NO	MAYBE	YES
1. are willing to say something about an error the teacher makes.	___	___	___
2. regularly volunteer to give the answer.	___	___	___
3. asks the math teacher to explain a problem again that is not understood.	___	___	___
4. think of another way to solve a word problem and volunteer to show the class.	___	___	___
5. review the word problems at the end of the class and evaluate if the lesson was understood.	___	___	___
6. answer questions about word problems in math class only to please the teacher.	___	___	___
7. volunteer to do word problems on the board so they can learn something more about math.	___	___	___
8. pay attention when the teacher explains word problems if they know there will be a test on them.	___	___	___
9. volunteer to do a word problem on the board if they think it will help their grade.	___	___	___
10. enjoy doing new word problems alone, even before the teacher explains them.	___	___	___
11. ask questions of the "what if" or "why" type.	___	___	___
12. follow directions.	___	___	___

	NO	MAYBE	YES
13. pay constant attention, regardless of knowledge of test content.	___	___	___
14. can't sit still and are involved in constant movement.	___	___	___
15. help other students.	___	___	___
16. take incomplete notes or none at all.	___	___	___
17. do not contribute to class discussions unless required to do so.	___	___	___
18. do not worry about making mistakes.	___	___	___
19. go beyond the textbook.	___	___	___
20. practice skills.	___	___	___

Appendix C

Student ALB Self-Report Questionnaire

Name ______________________________________

Circle: Girl Boy

The questions in this booklet ask about what you think and feel about doing math word problems. This is NOT a test. This is just a way for me to get your ideas about math. You will not be graded on your answers and the information will not affect your grades or school work, but you must answer every question. Please answer each question carefully.

PART I

First solve the problem. Use the space below to work on the problem. Then answer the statements about what you thought and did as you worked the problem.

Eight pennies are arranged in a row on a table. Every other coin is replaced with a nickel. Then, every third coin is replaced with a dime. Finally, every fourth coin is replaced with a quarter. What is the total value of the coins on the table?

Now go to the next page and say what you did.

BEFORE YOU BEGAN TO SOLVE THE PROBLEM-- WHAT DID YOU DO? Try to think of exactly what you did. Circle the answer that best describes what you think you did.

NO	MAYBE	YES
No, I didn't do this.	I may have done this.	Yes, I did do this.

1. I read the problem more than once.	NO	MAYBE	YES
2. I read the problem slowly.	NO	MAYBE	YES
3. I thought to myself, Do I understand what the question is asking me?	NO	MAYBE	YES
4. I tried to remember if I had worked a problem like this before.	NO	MAYBE	YES
5. I tried to put the problem into my own words.	NO	MAYBE	YES
6. I thought about what information I needed to solve this problem.	NO	MAYBE	YES
7. I looked for patterns in the problem.	NO	MAYBE	YES
8. I asked myself, Is there information in this problem that I don't need?	NO	MAYBE	YES
9. I wrote down important information.	NO	MAYBE	YES
10. I estimated the results.	NO	MAYBE	YES

AS YOU WORKED THE PROBLEM-- WHAT DID YOU DO? Circle the answer that best describes what you think you did.

1. I thought about all the steps as I worked the problem.	NO	MAYBE	YES
2. I kept looking back at the problem after I did a step.	NO	MAYBE	YES
3. I had to stop and rethink a step I had already done.	NO	MAYBE	YES
4. I checked my work step-by-step as I worked the problem.	NO	MAYBE	YES

5. I drew a picture or diagram to help me understand the problem.	NO	MAYBE	YES
6. I labeled a picture or diagram.	NO	MAYBE	YES
7. I picked out the operations I needed to do this problem.	NO	MAYBE	YES
8. I felt confused and could not decide what to do.	NO	MAYBE	YES
9. I didn't know how I was doing until I reached the final step.	NO	MAYBE	YES
10. I would have liked the teacher to check each step as I worked it.	NO	MAYBE	YES
11. I didn't get distracted and was able to concentrate on the problem.	NO	MAYBE	YES
12. I kept trying and did not want to "give up."	NO	MAYBE	YES
13. I worked backwards.	NO	MAYBE	YES
14. I worked quietly.	NO	MAYBE	YES
15. I was eager to get an answer.	NO	MAYBE	YES
16. I followed orderly procedure.	NO	MAYBE	YES
17. I really wanted to get the correct solution.	NO	MAYBE	YES

AFTER YOU FINISHED WORKING THE PROBLEM-- WHAT DID YOU DO? Circle
the answer that best describes what you think you did.

1. I looked back to see if I did the correct procedures.	NO	MAYBE	YES
2. I checked to see if my calculations were correct.	NO	MAYBE	YES
3. I went back and checked my work again.	NO	MAYBE	YES
4. I felt happy when I got an answer I felt was correct.	NO	MAYBE	YES

5. I looked back at the problem to see if my answer made sense.	NO	MAYBE	YES
6. I have no idea if my answer is correct-- I need someone to check it.	NO	MAYBE	YES
7. I didn't check my work.	NO	MAYBE	YES
8. I thought about a different way to solve the problem.	NO	MAYBE	YES

PART II

WHAT HAPPENS WHEN YOU WORK WORD PROBLEMS IN YOUR MATH CLASSROOM?
Think about when your teacher teaches about word problems. What do you do during your math class? Try to think of exactly what you do and answer NO MAYBE or YES to each statement.

NO	MAYBE	YES
No, I don't do this.	I may do this.	Yes, I do do this.

1. When my math teacher makes a mistake, I say something about the error.	NO	MAYBE	YES
2. I always like to volunteer and give my answer.	NO	MAYBE	YES
3. I ask my math teacher to explain a problem again that I do not understand.	NO	MAYBE	YES
4. When I can think of another way to solve a word problem, I volunteer to show the class.	NO	MAYBE	YES
5. When I review word problems at the end of the class, I evaluate if I understood the lesson.	NO	MAYBE	YES
6. I pay attention when my teacher explains word problems ONLY IF I know I will have a test on them.	NO	MAYBE	YES
7. I volunteer to do a word problem on the board ONLY IF I think it will help my grade.	NO	MAYBE	YES

8. I like to do new word problems by myself, even before the teacher explains them.	NO	MAYBE	YES
9. I usually ask questions of the "what if" and "why" type.	NO	MAYBE	YES
10. I always follow directions.	NO	MAYBE	YES
11. I like to pay close attention, even if I know the material won't be on a test.	NO	MAYBE	YES
12. I help other students.	NO	MAYBE	YES
13. I don't contribute to class discussions unless I really have to.	NO	MAYBE	YES
14. I don't worry about making mistakes.	NO	MAYBE	YES
15. I go ahead in the textbook, even if we're not up to that part yet.	NO	MAYBE	YES
16. I volunteer to do a word problem on the board, even if it won't help my grade.	NO	MAYBE	YES

Appendix D

Routine and Non-Routine Word Problem-Solving Task

Below you will find some word problems to solve. Please do not skip any--- you should work on all of the problems. Take your time and remember that you will not be graded on them. Your answers will not at all affect the grade you receive in your math class. Your math teachers will not know how you have performed on these problems. However, I do need you to work on the problems as best you can.

You have been given an answer sheet. Please use this answer sheet to record your answers and to work on the problems in the space provided.

1. One of Mr. Kaye's 2 motels has 24 rooms, which rent for $23.50 each. His other motel has 30 rooms, which rent for $26.75 each. When both motels are full, how much money is taken in?

2. The air distance between New York and Chicago is 1100 km.. The flight time is about 1 1/2 hours. How many kilometers are flown in 9 such flights?

3. A company that distributes computer supplies packaged 76.5 liters of cleaning fluid into 1.5 liter cans. If each can is sold for $.85, how much money will the company receive?

4. Tickets for the school play were sold at $3.00 each for adults and at $2.00 each for students. 205 student tickets were sold. How many adult tickets were sold if the total sales were $785.00?

5. Denise is 4 years younger than twice Leon's age. Denise is 28. How old is Leon?

6. Ms. Kandetu earned $9.20 an hour for the 38 1/2 hours she worked last week. What were her total earnings for the week?

7. A shop owner purchased 12 bicycles for $1235.76 and 8 skateboards for $472.64. What was the total cost of 1 bicycle and 1 skateboard?

8. A wine vat was only 1/2 full. After 4 empty wine bottles were filled, the wine vat was only 1/4 full. How many bottles could be filled if the wine vat were full?

9. A store bought 5 chairs for $39.75 each, 12 tables for $62.50 each, 20 lamps for $19.95 each, and 9 rugs for $79.85 each. How much did the store spend in all?

PLEASE TURN THE PAGE FOR THE NEXT PROBLEMS

These problems are all about WHALE WEIGHT!! Basically, you can estimate the weight of an adult gray whale if you know its length. For example, a whale that is 40 feet long weighs 40000 pounds. The chart below gives you additional information about this relationship.

Length		Weight
8 yards	----------	12 tons
26 1/2 feet	----------	26500 pounds
48.4 feet	----------	24.2 tons

Given this information, determine the missing information below:

	Length		Weight
10.	10 yards	----------	________

Hint: 3 feet = 1 yard

	Length		Weight
11.	________	----------	22 tons

Hint: 3 feet = 1 yard

12. A taxi company charges $.85 for the first 1/2 mile and $.45 for each additional 1/4 mile. What would be the cost of a 4.5 mile taxi ride?

Appendix E

Confidence in Learning Mathematics Scale

On the following page is a series of statements. There are no correct answers to these statements. They have been set up in a way that allows you to say just how much you agree or disagree with these ideas. Suppose the statement is:

Example 1. I like mathematics.

As you read the statement, you will know whether you agree or disagree. If you strongly agree, check the line under the words "strongly agree." If you agree, but not totally, that is, you do not fully agree, place a check on the line under the words "agree." If you neither agree nor disagree, place a check on the line under the words "neither agree nor disagree." If you disagree with the statement, either place a check on the line under "disagree" or "strongly disagree."

Do not spend much time with any statement, <u>but be sure to answer every statement</u>. Work fast but carefully.

There are no "right" or "wrong" answers. The only correct responses are those that are <u>true for you</u>. Whenever possible, let the things that have happened to you help you make a choice.

	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
1. Generally, I have felt secure about attempting mathematics.	_____	_____	_____	_____	_____
2. I am sure I could do advanced work in mathematics.	_____	_____	_____	_____	_____
3. I am sure that I can learn mathematics.	_____	_____	_____	_____	_____
4. I think I could handle more difficult math.	_____	_____	_____	_____	_____
5. I can get good grades in mathematics.	_____	_____	_____	_____	_____
6. I have a lot of self-confidence when it comes to math.	_____	_____	_____	_____	_____
7. I'm no good in math.	_____	_____	_____	_____	_____
8. I don't think I could do advanced math.	_____	_____	_____	_____	_____
9. I'm not the type to do well in math.	_____	_____	_____	_____	_____
10. For some reason even though I study, math seems unusually hard for me.	_____	_____	_____	_____	_____

11. Most subjects I can handle O.K., but I seem to have a knack for messing up in math. _____ _____ _____ _____ _____

12. Math has been my worst subject. _____ _____ _____ _____ _____

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