Structural Model of the Effects of Cognitive and Affective Factors on the Achievement of Arabic-Speaking Pre-service Teachers in Introductory Statistics

Fadia M. Nasser
Tel Aviv University and Beit Berl College

Journal of Statistics Education Volume 12, Number 1 (2004), ww2.amstat.org/publications/jse/v12n1/nasser.html

Copyright © 2004 by Fadia M. Nasser, all rights reserved. This text may be freely shared among individuals, but it may not be republished in any medium without express written consent from the author and advance notification of the editor.

Key Words: Achievement; Affective variable; Attitude toward mathematics; Cognitive variable; Mathematical aptitude; Mathematics anxiety; Statistics anxiety.

Abstract

This study examined the extent to which statistics and mathematics anxiety, attitudes toward mathematics and statistics, motivation and mathematical aptitude can explain the achievement of Arabic speaking pre-service teachers in introductory statistics. Complete data were collected from 162 pre-service teachers enrolled in an academic teacher-training program for elementary and middle schools in Israel. The data, except for the two achievement tests, were collected during statistics classes prior to the midterm examination. The majority (96%) of participants were female students with a mean age of 21. As regards variables examined in this study, only the hypothesized effect of mathematical aptitude on achievement in statistics was relatively large. The results also indicated that mathematical aptitude, mathematics anxiety, attitudes toward mathematics and statistics, and motivation, together accounted for 36% of the variance in achievement in introductory statistics for the current sample.

1. Introduction

Statistics courses have become an essential part of many programs in higher education. The rationale for teaching statistics at the college level is to enable students to handle, use, and interpret research or statistical data in their field of study. An additional goal of teaching statistics is to prepare students to deal effectively with statistical aspects of the world outside the classroom (Gal and Ginsburg 1994; Gal and Garfield 1997). Despite the effort that instructors of introductory statistics devote to simplifying the subject, many students encounter difficulties in their introductory statistics courses (Del Vecchio 1995; Glencross and Cherian 1992; Ossola 1970; Thompson and Smith 1982; Vidal-Madjar 1978; Watts 1991; Zeidner 1991). Perney and Ravid (1991, p. 2) demonstrated how critical these difficulties are by stating “statistics courses are viewed by most college students as an obstacle standing in the way of attaining their desired degree.” Cognitive factors (such as mathematical ability, mathematical background, and cognitive dimensions of attitudes towards mathematics and statistics) and affective factors (such as mathematics and statistics anxiety, motivation, and affective dimensions of attitudes toward mathematics and statistics) are some of the variables thought of as related to performance in statistics (Feinberg and Halprin 1978; Nasser 1999). Even though it has been recognized that affective factors may have long-term effects on students’ use of knowledge acquired in the classroom, statistics educators and researchers have primarily focused on cognitive skills and knowledge and paid much less attention to non-cognitive factors such as beliefs, feelings, attitudes and motivations (Gal and Ginsburg 1994; Krathwohl, Bloom, and Masia 1964). This study aimed to gain greater understanding of the nature and the potential influence of key cognitive and affective variables on the achievement of Arabic speaking pre-service teachers in introductory statistics. The importance of investigating the structure of achievement in statistics with this sample is twofold. First, research on the Arabic speaking population, notably in Israel, is sporadic, so this study can shed light on the structure of achievement in statistics in this
population. Second, studying statistics achievement of pre-service teachers is of particular importance because as teachers they will be expected to instill positive attitudes in their students regarding various aspects of statistics, such as design of experiments, data collection, data analysis and interpretation.

2. Literature Review

2.1 Mathematics and Statistics Anxiety

Many students experience anxiety when they are required to take statistics courses. Cruise, Cash, and Bolton (1985) argued that anxious students’ image of statistics is generally not a very positive one. Furthermore, students often enter their first statistics class with negative attitudes about learning quantitative subjects. These students experience mathematics anxiety (McLeod 1992), apprehension about taking tests (Hunsley 1987), and/or negative attitudes with respect to the relevance of statistics for their future careers (Roberts and Saxe 1982).

Cruise, et al. (1985) defined statistics anxiety as the feeling of anxiety encountered when taking a statistics course or doing statistics, that is, when gathering, processing and interpreting data. Furthermore, they indicated that statistics anxiety may stem, in part, from the need to use mathematics and therefore correlates with mathematics anxiety (Gal and Ginsburg 1994; Galagedera 1998; Galagedera, Woodward, and Degambodo 2000; Wooten 1998). They also contended that since statistics involves more than manipulating numbers, statistics anxiety might be a broader construct than mathematics anxiety. Other researchers (e.g., Del Vecchio 1995; Lalonde and Gardner 1993) argued that statistics anxiety might result in impaired performance, mental distress and avoidance of statistics courses needed for professional advancement. Furthermore, Ramsden (1992) suggested that any anxiety that students have about a subject affects their learning style.

The effect of anxiety on achievement is not agreed upon in the literature. For example, in the context of mathematics, Llabre and Suarez (1985) stated that mathematics anxiety had little to do with performance once anxious students were already enrolled in the course. Adams and Holcomb (1986) found that while mathematics anxiety was negatively related to performance in statistics, there was no significant relationship between performance in statistics and traditional measures of state and trait anxiety. In contrast, Lalonde and Gardner (1993) found an indirect negative relationship between what they referred to as “situational anxiety” and performance in statistics. More recently, Onwuegbuzie (1998, 2000) reported findings indicating that low achievement of college students was related to higher levels of statistics anxiety and low computation self-concept.

2.2 Attitudes toward Mathematics and Statistics

Theoretical and empirical issues related to attitudes have received much attention however, no single definition of attitudes emerged over the years (Gable and Wolf 1993). Currently-used definitions of attitudes incorporate common elements from several definitions. For example, Aiken (1980) merged several definitions to assert that:

> Attitudes may be conceptualized as learned predispositions to respond positively or negatively to certain objects, situations, concepts, or persons. As such they possess cognitive (beliefs or knowledge), affective (emotional, motivational), and performance (behavior or action tendencies) dimensions (1980, p. 2).

Simon and Bruce (1991) indicated that attitudes related to mathematics might play an effective role in students’ affective responses to statistics because students expect that learning statistics requires strong knowledge of mathematics. They also argued that by the time students start a formal statistics class, they will all have studied some level of mathematics at high school. Consequently, their affective reactions to the latter experience might affect their engagement and performance in statistics learning.

Consistent with Aiken’s general definition of attitudes, Olson and Zanna (1993) defined attitudes toward statistics as a multidimensional concept, which is composed of affective, cognitive and behavioral dimensions. Gal, Ginsburg, and Schau (1997) indicated that attitudes towards statistics have a potential role in influencing the learning process, students’ statistical behavior outside the classroom, and their willingness to attend statistics courses in the future. Furthermore, several researchers have discussed the relationship between attitudes and other personality traits. For example, Gal and Ginsburg (1994) noted that students’ preconceived ideas about the nature of statistics could produce anxiety. In support of this argument, Wisenbaker and Scott (1997) asserted that in their more intense form, negative attitudes might translate into anxiety. However, the literature makes little if any distinction between the concepts of attitudes and anxiety and the terms are often used interchangeably. The overlap between attitudes and anxiety is evident in measures of these two
Several researchers examined the relationship between attitudes toward mathematics and achievement in statistics and found conflicting results. For example, Adams and Holcomb (1986) found no significant relationship between attitudes toward mathematics and achievement in statistics while Feinberg and Halpin (1978) did find a relationship between the two. As to the relationship between attitudes toward statistics and achievement in statistics, a substantial part of the knowledge about this relationship came from validation of measures of attitudes toward statistics. In general, researchers (e.g., Lalonde and Gardner 1993; Nasser 1999; Roberts and Bilderback 1980; Schau, Dauphinee, Del Vecchio, and Stevens 1995; Wise 1985; Wisenbaker, Nasser, and Scott 1998; Wisenbaker, Scott, and Nasser 2000) have reported a small to moderate positive relationship between attitudes toward, and performance in, statistics. Wisenbaker, Scott, and Nasser (2000) further stated that this relationship appears to be fairly consistent regardless of the instrument used, the time of administration of either the attitudes or performance measure, or the level of the students.

2.3 Motivation

Psychologists concerned with learning and education usually use the word motivation to describe processes that (a) stimulate and induce behavior, (b) give direction or purpose to behavior, (c) continue to allow a certain behavior to persist, and (d) lead to choosing or preferring a certain behavior (Wlodkowski 1993). In research on young learners, where the relationship between motivation and learning has been frequently reviewed and analyzed, there is substantial evidence indicating that motivation is consistently and positively related to educational achievement (Uguroglu and Walberg 1979). Man, Nygård, and Giesme (1994) found a positive, albeit low, relationship between the motive-for-success score and school performance level as indicated by school grades in mathematics and English. In his study with 6th graders, Fontaine (1991) found that the more motivated students showed higher facilitating, lower debilitating anxiety, and expressed higher success expectations. It appears reasonable to assume that if motivation bears such a significant relationship to learning for young learners, it has a similar relationship to the learning of older students.

It is difficult to explain scientifically how motivation improves learning and achievement. However, Levin and Long (1981) claimed that the time that motivated students spend actively involved in learning is definitely related to achievement. They suggested that greater concentration and care are probably characteristics of the process for such students. Motivated students also tend to be more cooperative, which would make them more psychologically open to the learning material and enhance their information processing. Keller (1983) asserted that people work longer, harder and with more vigor and intensity when they are motivated than when they are not. Moreover, motivated learners get more out of the instruction than unmotivated learners. The literature we reviewed indicated that the distinct effect of motivation on achievement in statistics was not previously examined. Only the combined effect of motivation and attitudes on achievement in statistics through effort was assessed by Lalonde and Gardner (1993) who found this effect to be positive and significant.

2.4 Mathematical aptitude

Mathematical ability and background are frequently discussed in relation to achievement in statistics. Although it is often argued that understanding and applying statistics in empirical research does not require advanced mathematics, a significant and positive relationship between mathematical ability and performance has been consistently reported in the literature (Galagedera 1998; Galagedera, Woodward, and Degamboda 2000; Lalonde and Gardner 1993; Nasser 1998, 1999; Wooten 1998). For example, Galagedera (1998) found that first-year business mathematics and statistics students who were successful in mathematics at the university entry-level examination were more likely to do better in elementary statistics than poor performers at matriculation level. Wisenbaker, et al. (2000) argued that mathematical ability affects the acquisition of statistical skills and the two share a negative relationship with mathematics anxiety.

2.5 Correlates of Achievement in Statistics

The relationships among statistics and mathematics anxiety, mathematical aptitude, attitudes toward mathematics and statistics, and achievement in statistics were examined in a number of studies (Lalonde and Gardner 1993; Nasser 1998, 1999; Wisenbaker et al. 1998), and these relationships were not always clear. Over the past seven years Wisenbaker and his colleagues have been conducting research in which they used path analysis to predict statistics achievement from mathematical aptitude, mathematics anxiety and attitudes toward mathematics and statistics (Scott and Wisenbaker 1994; Wisenbaker and Scott 1995, 1997; Wisenbaker, Nasser, and Scott 1998; Wisenbaker, Scott, and Nasser 2000). The major finding from their studies has been that students’ attitudes toward statistics at the end of the statistics course were predictive of their achievement, while students’ attitudes toward statistics at the beginning of the course were not. Furthermore, they found a moderately positive relationship between mathematical aptitude and achievement in statistics.
The correlation between mathematics anxiety and achievement in statistics was also moderate but negative. It should be stressed that Wisenbaker and his colleagues did not include statistics anxiety in the models they tested. These researchers also did not address teacher effect or class variables, which may have contributed to the positive relationship found at the end of the statistics course.

Lalonde and Gardner (1993) used a version of their socio-educational structural model of second language acquisition (Lalonde and Gardner 1984) for predicting achievement in statistics. This version of their model included situational anxiety (statistics and number anxiety), attitudes, motivation intensity, mathematical aptitude, and effort as predictors of achievement in statistics. They found that a direct path between situational anxiety and achievement was not significant when the path between mathematical aptitude and achievement was present. Their results also suggested that the level of anxiety and the combination of attitudes and motivation could have indirect effects on achievement through effort.

2.6 The Research Model

Overall, the relationships among cognitive and affective variables underlying achievement in introductory statistics are not fully established in the literature. I used the available theoretical and empirical findings to hypothesize one of the potential structural models of achievement in statistics (see Figure 1). The hypothesized model included 19 manifest and seven latent variables. The assumption was that four of the seven latent variables (mathematical aptitude, mathematics anxiety, attitudes toward mathematics, and motivation) were precursors of learning statistics and therefore they were treated as exogenous, while the remaining three latent variables (attitudes toward statistics, statistics anxiety, and achievement in statistics) were treated as endogenous. As to structural relationships among the examined constructs, it was assumed that statistics anxiety decreases achievement in statistics (Onwuebuzie 1998, 2000) while high mathematical aptitude, high motivation, and positive attitudes toward statistics increase achievement in statistics (Gal and Ginsburg 1994; Gerson 1999; Man et al. 1994). It was assumed that negative attitudes toward statistics intensify statistics anxiety (Wisenbaker and Scott, 1997) and that greater motivation to succeed intensifies positive attitudes toward statistics (Auzmendi, 1991). According to the theorized model, attitudes toward mathematics and mathematical aptitude positively affect attitudes toward statistics, while mathematics anxiety inversely affects attitudes towards statistics (Gal and Ginsburg 1994; Wisenbaker et al. 1998).
3. Method

3.1 Participants

Complete data were collected from 162 Arabic speaking pre-service teachers enrolled in a teacher-training program for elementary and middle schools in an academic institution in Israel. The sample consisted predominantly of female students (96%) with a mean age of 21 years. Participants in this study represented the top 15% of applicants who met the strict entry criteria to the teacher education program. Therefore their academic level as measured by the matriculation (high school) scores and scores on the college entrance examination was above the average level of pre-service teachers in teacher training colleges in Israel. For all participants, introductory statistics was a required course and the same instructor taught it. No dropouts from the course were reported, which is to say that all participants completed the course including the midterm and the final examinations.

3.2 Variables and Measures

Seven latent variables were included in the proposed structural model. These variables and the corresponding measures are described below.
Achievement in Statistics

Scores on the midterm and final examinations (0-100 scale) in the introductory statistics course were used as measures of statistics achievement. Each of these achievement tests consisted of ten open-ended questions related to descriptive statistics (frequency tables, measures of central tendency, measures of dispersion, types of distributions, and measures of association) and inferential statistics (basic concepts in inferential statistics, estimation, hypothesis testing, t-test, Chi-square test, and types I and II errors).

The following is an example question taken from the midterm test:

The following table summarizes the results for two groups of college students in a midterm examination in introductory statistics.

| Statistic | Group 1 | Group 2 |
|-----------|---------|---------|
| Mean      | 77      | 90      |
| SD        | 11      | 15      |
| Mode      | 70      | 89      |
| Median    | 72      | 88      |
| Q1        | 65      | 75      |
| Q3        | 78      | 94      |

1. Which of the two groups is more homogeneous with regard to scores in introductory statistics? Explain your answer.
2. The distribution of which of the two groups' scores is closer to normal? Explain your answer.
3. What is the range of scores achieved by 50% of students in the first groups who are located in the center of the distribution? Explain your answer.

Both of the achievement tests were timed and open books and notes were allowed during the test. The total scores on the two statistics achievement tests were provided by the introductory statistics instructor, who was the only examiner, graded each of the examination questions. Cronbach's reliability of the scores on the midterm and the final tests (Score I and II) was .78 and .58 respectively.

Statistics Anxiety

The Arabic version of Cruise et al.'s (1985) Statistical Anxiety Rating Scale (STARS) was used to measure statistics anxiety. The English version consists of 51 statements organized in two parts. The first part includes 23 situations related to statistics anxiety. Participants responded to each possible anxiety-inducing situation (e.g., reading a journal article that includes some statistical analysis) by using a 1 to 5 scale, where 1 indicates that the situation causes no anxiety and 5 indicates that it causes a great deal of anxiety. The second part includes 28 statements describing respondent’s feelings towards statistics (e.g., I feel statistics is a waste). Responses to each statement ranged from 1 to 5, where 1 indicates strong disagreement to the content of the statement and 5 indicates strong agreement. High scores on the STARS mean more anxiety. Exploratory factor analysis performed by Cruise et al. (1985) led them to conclude that STARS measures six factors to which they referred as worth of statistics, interpretation anxiety, test/class anxiety, computation self-concept, fear of asking for help, and fear of statistics teachers. Actually, worth of statistics and computation self-concept are worthlessness of statistics and lack of computation self-concept and this is how they will be referred to hereafter.

Based on pilot results from an Arabic speaking sample of 170 pre-service teachers (Nasser 1999), twenty-four items were eliminated from the Arabic version due to departure from normality and minor item-total correlation coefficients (within each subscale). Exploratory factor analysis with principal factor axis extraction method and oblique rotation of the scores on the retained 27 items of the Arabic version of the STARS (Nasser 1999) indicated six factors, which accounted for 61% of the total variance. The number of items per factor ranged from three to seven and the reliability coefficients of the factor scores as measured by Cronbach’s $\alpha$ for the current sample ranged from .64 to .89. STARS was used in this study because it was believed, in light of the documented information, that it measures aspects that are specific to learning statistics, such as fear of statistics teachers. Furthermore, Cruise et al. (1985) documented the development and validation of the STARS (1985) and the scale was successfully used for measuring statistics anxiety in several studies (Bell 1998; Onwuegbuzie 1998, 2000).
**Attitudes Toward Statistics**

The Arabic version of Shau, Dauphinee, and Del Vecchio's (1995) Survey of Attitudes toward Statistics (SATS) was used to assess attitudes toward statistics. The original version of SATS (© 1995 Schau et al.) contained 32 Likert-type items; the current English version contains 28 items with a seven-point response scale ranging from 1 (strongly disagree) to 7 (strongly agree). High score indicates more positive attitudes. Schau et al. (1995) indicated that SATS measures four dimensions of attitudes toward statistics to which they referred as affect (e.g., I feel insecure when I have to do statistics), cognitive competence (e.g., I can understand statistics equations), value (e.g., statistical thinking is not applicable in my life outside my job), and difficulty (e.g., statistics is a subject quickly learned by most people). The Arabic version used in the current study consisted of 24 items. Four items were eliminated from the original due to minor item-total correlation coefficients and departure from the factor structure proposed by the SATS (© 1995 Schau et al.) developers. The number of items per factor ranged from four to eight and the internal consistency coefficients (Cronbach’s $\alpha$) of the factor scores from the present sample ranged from .65 to .80. It should be noted that some revisions were made on the instrument to suit one administration (the original SATS offers pre and post course measure of attitudes) at midway through the statistics course prior to the midterm test.

**Motivation**

Motivation was assessed by the Arabic version of the Motive for Success (MS) subscale of Nygård and Gjesme’s (1973) more comprehensive scale called Achievement Motivation Scale (AMS). The MS is a Likert-type scale, which consists of 15 positively, phrased items with four response points ranging from 1 (almost never) to 4 (almost always). Higher scores indicate more motivation to succeed. These items were devised to measure the capacity of individuals to anticipate positive feelings in achievement situations, which in turn was expected to affect their level of motivation to engage themselves in the achievement situation (Man, Nygård, and Gjesme 1994) (sample item: I feel pleasure when working on tasks that are somewhat difficult to me). The reliability coefficient associated with this scale for the present sample is .83. The MS scale was translated into different languages, such as German, Russian, Chinese and Arabic and was evaluated and characterized as well-tuned to achievement motivation theory (Man, Nygård, and Gjesme 1994).

**Attitudes Toward Mathematics**

The Arabic version of Fennema and Sherman's (1976) Mathematics Attitude Scale (MAS) was used to measure attitudes toward mathematics. The MAS is a ten-item Likert-type scale with seven response points, where 1 indicates strong disagreement and 7 strong agreement (sample item: Mathematics is very interesting and fun). Higher scores indicate more positive attitudes toward mathematics. Factor analysis with principal axis factoring as an extraction method yielded one factor when it was used with data from a previous sample of 170 Arabic speaking pre-service teachers drawn from the same population as the current sample (Nasser 1999). Cronbach's $\alpha$ for the mathematics attitudes scores in the present study is .93. This scale was selected for use in this study because it has a well-documented development and validation procedure (Fennema and Sherman 1976; Broadbrooks, Elmore, Pedersen, and Bleyer 1981) and it was extensively used to measure attitudes toward mathematics among American students and students from other countries (e.g., Nasser 1999; Wisenbaker et al., 1997, 1998).

**Mathematics Anxiety**

The Arabic version of Parker and Plake's (1982) Revised Mathematics Anxiety Rating Scale (RMARS) was used to measure mathematics anxiety. This Likert-type scale includes 24 statements designed to identify respondents' anxiety concerning a variety of activities related to mathematics in a statistics-related situation. Responses to the RMARS statements range from 1 (causes little anxiety) to 5 (causes high anxiety). Higher scores indicate higher levels of mathematics anxiety. Factor analysis conducted by Parker and Plake (1982) indicated two factors, which accounted for 60% of the total variance and to which they referred as “mathematics evaluation anxiety” (8 items) and “mathematics learning anxiety” (16 items). Parker and Plake (1982) reported an internal consistency coefficient (Cronbach’s $\alpha$) of .98 for the RMARS scores. Exploratory factor analysis with principal factoring axis extraction method and oblique rotation of RMARS scores from a sample of 170 Arabic speaking preservice teachers (Nasser 1999) indicated three factors, which accounted for 52% of the total variance. These three factors were referred to as mathematics evaluation anxiety (8 items, e.g., taking an examination in math course), mathematics learning anxiety (12 items, e.g., listening to a lecture in a math class), and mathematics interpretation anxiety (4 items, e.g., reading and interpreting graphs or charts). Internal consistency estimates (Cronbach's a) of scores on each of the three subscales and on the total scale, based on the present sample, were .84, .91, .84, and .94, respectively. RMARS was used for measuring mathematics anxiety in the current sample because it has a well-documented development process, high reliability and high predictive validity, based on a graduate sample (Parker and Plake 1982). RMARS also includes items that measure anxiety in a statistics related context.
and was widely used in various studies (Wisenbaker et al., 1997, 1998, 2000).

**Mathematical aptitude**

The number of mathematics units studied by the student and his/her rescaled high school mathematics grade (0-120 scale) were used to measure mathematical aptitude. Israeli high school students study mathematics at one of three different levels as indicated by the number of so-called units they take: low (3 units), intermediate (4 units), and high (5 units). These mathematics levels differ in content (mathematics topics covered) and depth of mathematics studies. Topics studied at the 3-unit level include basic algebra, geometry, trigonometry, and elective topics in introductory calculus and statistics. Actually, the latter two topics are rarely taught to students at this level. Topics included within the 4- and 5-unit mathematics curriculum are calculus (at different levels), probability and descriptive statistics alongside advanced algebra, trigonometry and geometry (especially at the 5-unit level). The high school mathematics grade is comparable across schools because it is obtained from a standardized national examination (matriculation) that is administered concurrently to all students who have studied mathematics at the same level. Higher education institutes rescale grades at different mathematics levels to make them comparable. The final numbers of items in each scale and the associated reliability coefficients (Cronbach’s $\alpha$) are presented in Table 1.

3.3 Procedure

Participants responded to all instruments, except the two achievement tests, during their statistics class prior to the midterm examination. The course instructor who taught the introductory statistics course used traditional instructional strategies and provided minimal evaluative feedback to students during the course (assignments were not graded and students were not given any credit for doing them). In addition, no computer software or computer assignments were involved in this introductory statistics course. The instructor’s teaching and evaluation styles are outlined here because they may have an effect on students’ attitudes, anxiety and achievement in relation to statistics and hence they should be taken into consideration in any interpretation of the results of this study.

4. Results

4.1 Descriptive and Correlational Analysis

The means, the standard deviations, as well as the values of skewness and kurtosis for participants' scores on each of the research variables, and the intercorrelations among these scores, were obtained and summarized in Table 1 and Table 2.

As shown in Table 1, the means of the two statistics scores were relatively high, yet, on average, the final test scores (score II) were higher and less variable than those on the midterm test (score I). In general, pre-service teachers expressed positive attitudes toward mathematics and statistics, were not anxious about mathematics and statistics and were moderately motivated to succeed. Furthermore, they demonstrated a relatively high mathematical aptitude as reflected by the mean number of mathematics units and high school mathematics scores. Participants’ impressive mathematics grades are not surprising given the strict criteria for acceptance to the teacher-training program. The variability of students’ mathematics and statistics scores and their responses to the cognitive and affective measures as indicated by the standard deviations were reasonable given the way they were measured.

Screening data for nonnormality prior to conducting the testing is an important step in every multivariate analysis because departure to a significant degree from normality if not addressed can distort the results of the data analysis (Fan, Thompson, and Wang 1999; Fidell and Tabachanick 2003; Nasser and Wisenbaker 2002; Tabachanick and Fidell 2001; West, Fich, and Curran 1995). Several methods for assessing nonnormality were proposed in literature. The most common are testing the significance of the skewness and kurtosis values by means of Z test with conservative p value (.01 or .001), frequency histograms and/or normal probability plots (Bollen 1989; Tabachnick and Fidell 2001).

---

**Table 1. Number of Items, Means and Standard Deviations of Scores on the Manifest Variables (N=162)**

| Manifest Variable | Mean | Standard Deviation | Skewness | Kurtosis |
|-------------------|------|--------------------|----------|----------|
| Math Aptitude      |      |                    |          |          |
| Math Units         |      |                    |          |          |
| Math Grade         |      |                    |          |          |

8 of 19
In the Results Coach section of SPSS 11 it was indicated that, in general, skewness or kurtosis values greater than 1 indicate a distribution that differs significantly from the normal symmetric distribution (SPSS 11, results coach), this criterion was used to detect nonnormality in the present study.

Stat score II, lack of computation self-concept, and fear of stat teachers scores had skewness and kurtosis that exceeded 1. The first measure was negatively skewed while the latter two were positively skewed. These three measures were corrected for nonnormality using Fox’s (1997, p. 67) method whereby stat score II (negatively skewed) was transformed using power transformation ($x$ to $x^2$), while lack of computation self-concept and fear of statistics teachers scores (positively skewed) were transformed using log transformation ($x$ to log$x$). The skewness and kurtosis values for the remaining measures were all below 1 and were assumed to be within the expected range of chance fluctuation in these statistics.

Pearson product moment correlation coefficients between each of the affective and cognitive measures and the two measures of achievement in statistics are presented in the left two columns of Table 2. As can be seen in Table 2, these correlation coefficients ranged from nil to moderate (.04-.42). Two observations are worth mentioning as regards these correlations. First, the magnitude of the correlations between the cognitive and affective variables examined in the current study, and the first statistics score were, in general, somewhat higher than their counterparts with the second statistics score. Second, the two statistics test scores correlated .30 to .42 with the two mathematical aptitude measures. Medium correlations were also found between the two statistics test scores and the measure of attitudes towards mathematics (.35 and .34). Correlations equal to or larger than .20 (in absolute value)

| Variable                          | Number of items | $\bar{X}$ | $SD$ | $\alpha$ | Skewness | Kurtosis |
|-----------------------------------|-----------------|----------|------|----------|----------|----------|
| **Statistics Achievement (0-100)**|                 |          |      |          |          |          |
| 1. Stat score                     | 10              | 78.06    | 18.30| .78      | -0.91    | 0.27     |
| 2. Stat score II                  | 10              | 83.38    | 12.67| .88      | -1.49    | 2.77     |
|                                  |                 | 7448.62  | 1949.92|          | -0.91    | 0.54     |
| **Statistics Anxiety (1-5)**      |                 |          |      |          |          |          |
| 3. Worthlessness of statistics    | 7               | 2.00     | 0.83 | .89      | 0.99     | 0.71     |
| 4. Fear of asking for help        | 4               | 1.89     | 0.77 | .73      | 0.71     | -0.32    |
| 5. Test/class anxiety             | 4               | 3.28     | 0.97 | .83      | -0.22    | -0.34    |
| 6. Interpretation anxiety         | 5               | 2.35     | 0.74 | .69      | 0.23     | -0.14    |
| 7. Lack of computation self-concept | 4   | 1.54     | 0.67 | .75      | 1.38     | 1.60     |
|                                  |                 | 0.15     | 0.17 |          | 0.74     | -0.57    |
| 8. Fear of stat teachers          | 4               | 1.44     | 0.50 | .64      | 1.35     | 2.11     |
|                                  |                 | 0.14     | 0.13 |          | 0.68     | -0.44    |
| **Attitudes toward Statistics (1-7)** |   |          |      |          |          |          |
| 9. Cognitive                      | 6               | 5.29     | 1.11 | .79      | -0.47    | -0.30    |
| 10. Value                         | 8               | 4.72     | 1.06 | .80      | 0.32     | 0.24     |
| 11. Difficulty                    | 4               | 3.38     | 1.10 | .63      | 0.06     | -0.50    |
| 12. Affect                        | 6               | 4.82     | 1.32 | .74      | -0.24    | -0.63    |
| **Motivation**                    |                 |          |      |          |          |          |
| 13. Motive to succeed (1-4)       | 15              | 2.51     | 0.46 | .83      | 0.29     | -0.19    |
| **Attitudes towards Mathematics (1-7)** | 10  |          |      |          |          |          |
| 14. Math attitudes                | 10              | 4.99     | 1.47 | .92      | -0.33    | -0.28    |
| **Mathematics Anxiety (1-5)**     |                 |          |      |          |          |          |
| 15. Learning anxiety              | 12              | 2.28     | 0.89 | .84      | 0.52     | -0.32    |
| 16. Evaluation anxiety            | 8               | 3.37     | 1.08 | .91      | -0.71    | -0.52    |
| 17. Interpretation anxiety        | 4               | 2.23     | 0.82 | .84      | 0.47     | -0.23    |
| **Mathematical aptitude**         |                 |          |      |          |          |          |
| 18. Math units (3-5)              |                 | 3.73     | 0.70 |          | 0.40     | -0.91    |
| 19. Math score (0-120)            | 11, 8, and 10^7 | 91.73    | 12.08| .54      | -0.13    | 0.38     |

1 In second line transformed scores.
2 For 3-, 4-, and 5-unit level respectively.
were found between the first statistics score and each one of: the lack of computation self-concept component of statistics anxiety, the cognitive component of attitudes toward statistics, and the learning and interpretation components of mathematics anxiety. The counterpart correlations with the second statistics score were similar except the one with the interpretation component of mathematics anxiety, which was smaller than .20. The correlations between the two statistics scores and the remaining cognitive and affective factors ranged from about zero to small ($r<=.20$). All nonzero correlations were in the expected direction and those equal to or greater than .16 (absolute value) were statistically significant.

As to the correlations between measures of statistics and mathematics anxiety, attitudes towards mathematics and statistics, the most salient correlations were observed between the cognitive component of attitudes towards mathematics and the lack of computation self-concept component of statistics anxiety (-.62), between the worthlessness of statistics component of statistics anxiety and the value component of attitudes towards statistics (-.76), between mathematics attitudes and measures of learning, evaluation, and interpretation mathematics anxiety (-.76, -.57, -.61, respectively), and between test/class anxiety and mathematics evaluation anxiety (.62).

Table 2. Summary of Correlation Coefficients between the Manifest Variables (N=162)

| Variables                                      | 1    | 2    | 3    | 4    | 5    | 6    | 7    | 8    | 9    | 10   | 11   | 12   | 13   | 14   | 15   | 16   | 17   | 18   |
|------------------------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| Statistics Achievement (0-100)                |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 1. Stat score 1                               |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 2. Stat score 2                               | 0.68 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Statistics Anxiety (1-5)                      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 3. Worthlessness of statistics                |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 4. Fear of asking for help                    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 5. Test class/anxiety                         |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 6. Interpretation anxiety                     |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 7. Lack of computation self-concept          |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 8. Fear of statistics teachers                |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Attitudes toward Statistics (1-7)             |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 9. Cognitive                                  | 0.28 | 0.28 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 10. Value                                     | 0.18 | 0.12 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 11. Difficulty                                | 0.11 | 0.11 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 12. Affect                                    | 0.17 | 0.18 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Motivation                                    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 13. Motive to succeed (1-4)                   | 0.11 | 0.05 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 14. Motive to succeed (1-4)                   |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 15. Motive to succeed (1-4)                   |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 16. Motive to succeed (1-4)                   |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 17. Motive to succeed (1-4)                   |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 18. Motive to succeed (1-4)                   |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
Note. Correlation coefficients equal or greater than .16 are statistically significant at \( \alpha = .05 \).

The correlations between the transformed values of stat score 2, lack of computation self-concept, and fear of statistics teachers and other variables are reported in the table.

### 4.2 Structural Modeling Analysis

In order to examine the relationship between achievement in statistics and cognitive and affective variables, a structural equation modeling (SEM) analysis via EQS (version 5.7b) procedure was employed. This procedure allows an assessment of the adequacy-of-fit of a theoretical (hypothesized) model to the data, as indicated by the degree to which the specified model leads to an exact reproduction of the population covariance matrix of the manifest variables (Bollen and Long 1993). The structural modeling approach tends to serve two general purposes in research: evaluating the degree to which the hypothesized model fits the data at hand, and estimating the parameters. A structural model with acceptable fit informs the researcher that the empirical relationships among the variables are consistent with those implied by the model whereas model parameter estimates indicate the magnitude and the direction of the relationships among the variables.

The first indicator in each multi-indicator construct was selected as an indicator variable (fixed to 1) to set the scale and the error for the single-indicator constructs was fixed to \( e = \text{variance of the associated variable multiplied by (1- Cronbach’s } \alpha) \) (McDonald and Seifert 1999).

The hypothesized structural model (Figure 1) yielded a very poor fit. Furthermore, a warning in the output indicated that test results might not be appropriate due to a condition code whereby statistics anxiety and mathematics anxiety are linearly dependent on other variables. The aforementioned diagnosis led to the conclusion that the initial intent of assessing statistics anxiety separately from attitudes toward statistics and mathematics anxiety using the SATS (© 1995 Schau et al.), RMARS, and the STARS scales proved to be unsuccessful. The practical translation of this conclusion was removing one of the anxiety constructs from the model. Because mathematics anxiety measures for the current sample were more reliable than four of the six measures of statistics anxiety, the relationship of mathematics anxiety with attitudes toward statistics and therefore with achievement in statistics, is better established in the literature than the parallel relationships, but with regard to statistics anxiety, and since the RMARS includes items that measure anxiety in a statistics-related context, it was decided to retain mathematics anxiety in the model while leaving out statistics anxiety.
Because the original model did not fit the data well an alternative model (Model I) was tested. Model I was similar to the original one except for excluding statistics anxiety, and fit the data well (see Table 3). Nonetheless, three structural paths in Model I were statistically not significant (p > 0.05). These corresponded with the effect of motivation on achievement in statistics, in the presence of the effects of attitudes toward statistics and mathematical aptitude, and the effects of attitudes toward mathematics and mathematical aptitude on attitudes toward statistics, in the presence of the effects of motivation and mathematics anxiety. Consequently, three additional alternative models were tested (Models II to IV). Model II resulted from discarding (fixing to zero) the insignificant path between motivation and achievement in statistics from Model I. Model III was created by removing the insignificant path between attitudes towards mathematics and attitudes toward statistics from Model II. Model IV resulted from discarding the path between mathematical aptitude and attitudes toward statistics from Model III (see Table 3). The $\chi^2$ difference ($\Delta \chi^2$, df=1) between the successive alternative models was not statistically significant. The goodness-of-fit results for the originally hypothesized model and the four alternative ones are shown in Table 3, and the most parsimonious model (Model IV) is displayed in Figure 2.

All the measurement coefficients in the final model (Model IV) are in the expected direction (positive) and statistically significant. Of more interest for understanding the structure of achievement in statistics was the structural part of the model. Strong mathematical aptitude and more positive attitudes toward statistics increased achievement in statistics. Although both effects were statistically significant, the hypothesized effect of mathematical aptitude on achievement in statistics was substantially larger than that of attitude toward statistics. The hypothesized effects of motivation and mathematics anxiety on attitudes toward statistics were statistically significant (p < 0.05). Results indicated that stronger motivation to succeed and lower level of mathematics anxiety intensified positive attitudes toward statistics. However, the effect of mathematics anxiety on attitudes toward statistics is relatively large as compared with the counterpart effect of motivation.

| Model                                      | $\chi^2$ | df  | p    | $\Delta \chi^2$ | GFI  | NNFI | CFI  | RMSEA |
|--------------------------------------------|----------|-----|------|------------------|------|------|------|-------|
| Hypothesized model (Figure 1)              | 373.47   | 137 | .001 | 2.73             | .817 | .772 | .817 | .104  |
| Model I - without statistics anxiety       | 39.87    | 54  | .271 | 1.11             | .947 | .989 | .993 | .027  |
| Model II - without statistics anxiety       | 60.26    | 55  | .291 | 1.10             | .946 | .991 | .994 | .025  |
| Model III - without motivation             | 60.27    | 56  | .334 | 1.08             | .946 | .993 | .995 | .023  |
| Model IV - without attitude towards         | 60.59    | 57  | .338 | 1.06             | .946 | .994 | .995 | .021  |

As for amount of variance accounted for, it was found that mathematical aptitude, mathematics anxiety, attitudes toward mathematics, attitudes toward statistics and motivation, together, accounted for 36% of the variance in achievement in the introductory statistics course. In other words, 36% of the variance in achievement in statistics can be explained by the cognitive and affective factors included in the model. It was also shown that mathematical aptitude alone accounted for 22% of the variance in achievement in statistics, while the remaining affective and cognitive variables accounted for 14% of the variance in achievement in statistics.
It is important to note that the combination of mathematical aptitude, mathematics anxiety, attitudes toward mathematics and motivation accounted for a substantial (51%) amount of the variance in attitudes toward statistics.

5. Summary and Discussion

Consistent with findings from previous studies (Lalonde and Gardner 1993; Nasser 1998, 1999; Wisenbaker, Nasser, and Scott 1998) this study revealed that the correlations between the two measures of statistics achievement and measures of mathematical aptitude, attitudes towards mathematics, the cognitive component of attitudes toward statistics, learning anxiety and lack of computation self-concept, were all moderate (.21 to .42 in absolute values) (Cohen 1988). Meanwhile, the correlations between the two measures of achievement in statistics and the remaining variables were small (|r| < .2).

On the one hand, it might be that these results reflect the actual magnitude of the relationships between the examined variables. On the other hand, it is possible that the unique characteristics of the sample (mostly female students with strong mathematical aptitude and limited variability in their responses to some of the manifest variables) and the low reliabilities (below .70) of five of the 19 measures are responsible for the modest (attenuated) correlations.

The two measures of mathematics and statistics anxiety and the two measures of attitudes toward mathematics and statistics were correlated in the expected direction. The nontrivial correlations among several measures of anxiety and attitudes related to statistics lend some support to the widely known argument that feelings about statistics may stem from
feelings about mathematics. This is known to be especially so with students who have either limited prior experience in statistics or none, as was the case with the sample in this study. These results also raise a question regarding the extent to which attitudes and anxiety as measured in the current study are distinct constructs. Furthermore, Wisenbaker and Scott’s (1997) claim that negative attitudes may convert to anxiety provides a reasonable interpretation for the negative significant correlation between measures of these two constructs. The results of the present study also provide some confirmation for Gal and Ginsburg’s (1994) argument that students’ preconceptions regarding the nature of statistics (as requiring high cognitive ability) could produce anxiety.

The unsuccessful attempt to measure statistics anxiety separately from attitudes toward statistics and from mathematics anxiety resulted in a poor fit of the hypothesized model to the data. The alternative model, in which statistics anxiety was removed, yielded an adequate fit although it included three insignificant structural coefficients. The three other alternative models from which an ascending number of insignificant paths were removed, one at a time, also fit the data well. The most parsimonious model (Model IV) explained about the same amount of variance in achievement of ‘statistics as the other, less parsimonious, alternative models (36% and 37%, respectively).

As to parameter estimates, particularly the structural coefficients, the small, but positive ($\beta$=.15) significant effect of attitudes toward statistics on achievement in statistics, in the presence of the path between mathematical aptitude and achievement in statistics, is consistent with findings from previous research (Nasser 1999; Wisenbaker, et al. 1998, 2000). Motivation had a significant, albeit small, positive effect on attitudes toward statistics and a minor mediated positive effect (through attitudes toward statistics) on achievement in statistics. The existing literature yields no empirical basis for interpreting the link between motivation and achievement in statistics. Despite the theoretical, and some empirical, findings linking motivation with achievement in different subjects (Man et al. 1994), to our knowledge, the link between these two constructs was not examined so far. Although motivation was one of the variables that Lalonde and Gardner (1993) examined in relation to achievement in statistics, only the combined effect of motivation and attitudes on achievement in statistics through effort was examined. Thus the distinct effect of motivation on achievement in statistics has not been studied so far. In contrast, the positive but modest effect of motivation on attitudes concords with findings reported by Auzmendi (1991). The modest and minor effects that motivation has on attitudes toward statistics and on achievement in statistics may also be associated with validity problems caused by using a measure of general motive for success as an indicator of achievement motivation in a specific context such as statistics. To be realistic, it is important to point out that although motivation is a necessary condition for learning, there are other factors, such as quality of instruction, type of evaluative feedback, amount of effort, expectations, self efficacy and self regulation that are required as well, and they therefore, are recommended to be subject to future research.

Despite the frequently heard argument that understanding and applying statistics to empirical data does not require advanced mathematics (e.g., Galagedera, Woodward, and Degamboda 2000; Lalonde and Gardner 1993), mathematical aptitude accounted for 22% of the variance in statistics achievement while the remaining cognitive and affective variables together explained only 14% of the variance in achievement in statistics. Thus mathematical aptitude turned out to be the most important among the variables used in the current study for modeling the structure of achievement in statistics. That is, mathematical aptitude was the best predictor of achievement in statistics for the current sample and for how achievement was defined in this study. The dominance of mathematical aptitude for predictability of achievement in statistics confirms findings reported in previous research (Lalonde and Gardner 1993; Nasser 1998, 1999; Wisenbaker and Scott 1997). It was shown that a stronger mathematical aptitude is associated with more positive attitudes toward mathematics and statistics, lower levels of mathematics anxiety, and higher achievement in statistics. Therefore, any remedial plans for improving students’ feelings about, and achievement in, statistics should improve their mathematics ability and their feelings toward mathematics and statistics. It is reasonable to believe that strengthening one of these components while ignoring the other, will compromise the outcomes of teaching statistics.

In spite of the modest effects of some of the affective variables on achievement in introductory statistics, they can, alongside mathematical aptitude, explain a considerable amount of the variance in achievement in statistics (36%). It should be reiterated that the substantial improvement in the goodness of model fit as a result of removing statistics anxiety implies that the attempt using STARS to measure statistics anxiety separately from mathematics anxiety and attitudes toward statistics was unsuccessful. It is plausible that the measures of statistics anxiety and attitudes toward statistics, which were used in the current study, targeted similar dimensions of the two constructs. However, if one believes that these are indeed two separate constructs, more careful work should be done to refine their definitions and to develop instruments that yield more accurate and valid scores. Furthermore, the temporal spacing between the collection of the attitude, anxiety, motivation data, the midterm, and then the final test, might have affected the variability of the responses and their relationships as well.

The study was limited by the fact that the sample consisted of a vast majority of able female students in a teacher training
college, so that the structural model reported here may not generalize to different samples. Another limitation of the study is rooted in the assessment method by which achievement was measured. Two points are noteworthy in this regard. First, achievement was assessed by a limited number of open-ended questions. Given the limited ability of this kind of questions to adequately represent the learned materials and skills and given the subjectivity involved in this type of evaluation, the ability of the two scores to adequately represent achievement in statistics is uncertain. Second, reliance on only one method of assessment (written examinations with open-ended questions), as is the case in the current study, does not allow for adequate evaluation of student performance (Gal and Garfield 1997; Colvin and Vos 1997; Gal and Garfield 1997; and Schau and Mattern 1997; among others, have argued that in order to properly assess student performance in statistics, various assessment methods should be applied in order to reveal students' understanding of the major ideas in statistics and their ability to select and adequately apply statistical tools when making sense of realistic data. This was not done in the current study. Further research is called for to test the validity and the generalizability of the current results and conclusions. This study is also limited by the fact that it did not address changes over time. Attitudes and feelings about statistics can change in the course of learning the subject so that the magnitude and/or the direction of the relationships in the structural model can also change.

At issue are also the sample size and the low reliability of some of the measures specially that of the second statistics test scores. As indicated by results from previous studies, small sample size especially with highly parameterized models and low reliability of indicators, as was the case in the present study, can have an adverse effect on the variance of parameter estimates (Gerbing and Anderson 1985; Jackson 2001; ) and values of summary fit indexes (Anderson and Gerbing 1984; Marsh, Hau, Balla, and Grayson 1998; Nasser and Wisenbaker 2002). In order to assess the impact of these two factors and to test the accuracy and validity of the results reported here, further research with a larger sample and more reliable measures is imperative.

Regardless of the above limitations, it is reasonable to conclude that the direction and the magnitude of the correlations between affective and cognitive factors and their effects on achievement in statistics of Arabic speaking pre-service teachers are, in general, consistent with findings reported in the literature. However, this conclusion should be empirically tested in a cross-cultural study, which is recommended for future research. It is also important to indicate that although modest, the results of the current study contributed to the scant knowledge about the structure of achievement in statistics and furnished the basis for the further research that is needed to address unresolved questions involving learning statistics. Findings also have implications for planning and teaching this subject. For example, it might be necessary and beneficial to design remedial mathematics courses to be taken prior to or concurrently with introductory statistics courses in order to improve mathematical aptitude, decrease mathematics anxiety, intensify positive attitudes toward mathematics, and consequently strengthen positive motivation. This in turn, will improve attitudes towards and achievement in statistics. However, there is still a long way to go if we want to gain a comprehensive understanding of correlates of students' achievement in statistics, and if we wish to make statistical studies pleasant as well as successful.

Acknowledgements

The author wish to thank Dr. Joseph Wisenbaker, Dr. Barbara Fresko, the Editor, the Associate Editor and the two anonymous reviewers for their comments.

References

Adams, N. A., and Holcomb, W. R. (1986), "Analysis of the relationship between anxiety about mathematics and performance," Psychological Reports, 59, 943-948.

Aiken, L. R. (1980), "Attitudes measurement research," in Recent developments in affective measurement, ed. D. A. Payne, San Francisco: Jossey-Bass, pp. 1-24.

Anderson, J. C., and Gerbing, D. W. (1984), "The effect of sampling error on convergence, improper solutions, and goodness-of-fit indices for maximum likelihood confirmatory factor analysis," Psychometrika, 49, 155-173.

Auzmendi, E. (1991, April), "Factors related to attitudes toward statistics: A study with a Spanish sample," paper presented at the Annual Meeting of the American Educational Research Association, Chicago, IL.
Bell, A. J. (1998), "International students have statistics anxiety too," *Education*, 118, 634-636.

Bollen, A. K. (1989), *Structural equations with latent variables*, New York: Wiley.

Bollen, A. K., and Long, J. S. (1993), *Testing structural equation models*, Newbury Park, CA: Sage.

Broadbrooks, J. W., Elmore, B. P., Pederson, K., and Bleyer, R. D. (1981), "A construct validation study of the fennema-sherman mathematics attitudes scales," *Educational and Psychological Measurement*, 41, 551-557.

Cohen, J. (1988), *Statistical power analysis for the behavioral sciences* (2nd ed.), Hillsdale, NJ: Erlbaum.

Colvin, S., and Vos, E. K. (1997), "Authentic assessment models for statistics education," in *The assessment challenges in statistics education*, eds. I. Gal and J. B. Garfield, Amsterdam: IOS, pp. 27-36.

Cruise, J. R., Cash, R. W., and Bolton, L. D. (1985), "Development and validation of an instrument to measure statistical anxiety," in *Proceedings of the Section on Statistical Education*, American Statistical Association, pp. 92-98.

Del Vecchio, A. (1995), "A psychological model of introductory statistics course completion," paper presented at the annual meeting of the American Educational Research Association, San Francisco, CA.

Fan, X., Thompson, B., and Wang, L. (1999), "The effects of sample size, estimation methods, and model specification on SEM fit indices," *Structural Equation Modeling*, 6, 56-83.

Feinberg, F., and Halprin, S. (1978), "Affective and cognitive correlates of course performance in introductory statistics," *Journal of Experimental Education*, 46, 11-18.

Fennema, L., and Sherman, J. A. (1976), "Fennema-Sherman mathematics attitude scales: Instruments designed to measure attitude toward the learning of mathematics by females and males," *Journal for Research in Mathematics Education*, 7, 324-326.

Fidell, L., and T. Tabachnick, G. B. (2003), "Preparatory data analysis," in *Handbook of psychology: Research methods in psychology* (Vol. 2), eds. A. J. Schinka and W. F. Velicer, New York, John Wiley & Sons, pp. 115-141.

Fontaine, M. A. (1991), "Impact of social context on the relationship between achievement motivation and anxiety, expectation or social conformity," *Personality and Individual Differences*, 12, 457-466.

Gable, K. R. and Wolf, B. M. (1993), *Instrument development in the affective domain* (2nd ed.), Boston: Kluwer.

Gal, I., and Garfield, J. B. (1997), "Curricular goals and assessment challenges in statistics education," in *The assessment challenges in statistics education*, eds. I. Gal and J. B. Garfield, Amsterdam: IOS, pp. 1-13.

Gal, L. B., and Ginsburg, L. (1994), "The rule of beliefs and attitude in learning statistics: toward an assessment framework." Journal of Statistics Education [Online], 2(2). [ww2.amstat.org/publications/jse/v2n2/gal.html](http://www2.amstat.org/publications/jse/v2n2/gal.html)

Gal, L. B., Ginsburg, L., and Schau, C. (1997), "Mentoring attitudes and beliefs in statistics education," in *The assessment challenges in statistics education*, eds. I. Gal and J. B. Garfield, Amsterdam: IOS, pp. 37-51.

Galagedera, D. (1998), "Is remedial mathematics a real remedy? Evidence from learning statistics at tertiary level," *International Journal of Mathematics Education, Sciences and Technology*, 29, 475-480.

Galagedera, D., Woodward, G., and Degamboda, S. (2000), "An investigation of how perceptions of mathematics ability can affect elementary statistics performance," *International Journal of Mathematics Education, Sciences and Technology*, 31, 679-689.

Gerbing, D. W., and Anderson, J. C. (1985), "The effects of sampling error and model characteristics on parameter estimation for maximum likelihood confirmatory factor analysis," *Multivariate Behavioral Research*, 20, 255-271.

Gerson, F. R. (1999), "The people side of performance improvement," *Performance Improvement*, 38, 19-23.
Glencross, M. J., and Cherian, V. I. (1992), "Attitude toward applied statistics of postgraduate students in Transco," *Psychological Reports*, 70, 67-75.

Hunsley, J. (1987), "Cognitive processes in mathematics anxiety and test anxiety: the rule of appraisals, internal dialogue and attributions," *Journal of Educational Psychology*, 79, 388-392.

Keller, L. M. (1983), "Motivational design instruction," in *Instructional design theories and models: An overview of their current status*, ed. C. M. Reigeluth, Hillsdale, N. J.: Erlbaum.

Krathwohl, D. R. Bloom, B. S., and Masia, B. B. (1964), *Taxonomy of educational objectives: The classification of educational goals, Handbook II: Affective domain*, New York: David.

Lalonde, R. N., and Gardner, R. C. (1984), "Investigating a causal model of second language acquisition: Where does personality fit?," *Canadian Journal of Behavioral Science*, 16, 224-237.

Lalonde, R. N., and Gardner, R. C. (1993), "Statistics as a second language: Predicting performance of psychology students," *Canadian Journal of Behavioral Science*, 25, 108-125.

Levin, T., and Long, R. (1981), *Effective instruction*, Alexandria, VA: Association for Supervision and Curriculum Development.

Llabre, M., and Suarez, E. (1985), "Predicting math anxiety and course performance in college women and men," *Journal of Counseling Psychology*, 32, 283-287.

Man, F., Nygård, R., and Gjesme, T. (1994), "The achievement motives scale (AMS): theoretical basis results from a first try-out of Czech form," *Scandinavian Journal of Educational Research*, 38, 3-4.

Marsh, H. W., Hau, K.-T., Balla, J. R., and Grayson, D. (1998), "Is more ever too much? The number of indicators per factor in confirmatory factor analysis," *Multivariate Behavioral Research*, 33, 181-220.

McDonald, A. R., and Seifert, F. C. (1999, October), "Full and limited information strategies for incorporating measurement error in regression models," paper presented at the Southern Management Association Meeting. Atlanta GA.

McLeod, D. B. (1992), "Research on affect in mathematics learning in the JRME: 1970 to present," *Journal of Research in Mathematics Education*, 25, 637-647.

Nasser, F. (1998, July), "Attitude toward statistics and statistics anxiety among college students: Structure and relationship to prior mathematics experience and performance in introductory statistics course," paper presented at the Annual Meeting of the Stress and Anxiety Society (STAR), Istanbul, Turkey.

Nasser, F. (1999), "Prediction of statistics achievement," in *Proceedings of the International Statistical Institute 52nd Conference*, Helsinki, Finland, (3), pp. 7-8.

Nasser, F., and Wisenbaker, J. (2002, April), "A Monte Carlo study investigating the impact of item parceling strategies on measures of fit in confirmatory factor analysis," paper presented at the Annual Meeting of the American Educational Research Association. New Orleans, LA.

Nygård, R., and Gjesme, T. (1973), "Assessment of achievement motives: comments and suggestions," *Scandinavian Journal of Educational Research*, 17, 39-46.

Olson, J. M., and Zanna, M. P. (1993), "Attitude and attitude change," *Annual Review of Psychology*, 44, 117-154.

Onwuegbuzie, J. A. (1998), "Statistics anxiety: A function of learning style?", *Research in Schools*, 5, 43-52.

Onwuegbuzie, J. A. (2000), "Statistics anxiety and the role of self-perception," *Journal of Educational Research*, 93, 323-330.
Ossola, Y. (1970), "Attitude toward statistics of Flemish students in psychology and education," *Psychological Belgica*, 10, 83-98.

Parker, C. S., and Plake, B. S. (1982), "The development and validation of the Revised Version of the Mathematics Anxiety Rating Scale," *Educational and Psychological Measurement*, 42, 551-557.

Perney, J., and Ravid, R. (1991), "The relationship between attitude toward statistics, mathematics self-concept, test anxiety and graduate students' achievement in introductory statistics course," unpublished manuscript, National College of Education, Evanston, IL.

Ramsden, M. J. (1992), "If it's enjoyable, is it science?," *School Science Review*, 73, 65-71.

Roberts, D. M., and Bilderback, E. W. (1980), "Reliability and validity of the of a statistics attitude survey," *Educational and Psychological Measurement*, 40, 235-238.

Roberts, D. M., and Saxe, J. E. (1982), "Validity of statistics attitude survey: A follow up study," *Educational and Psychological Measurement*, 42, 907-912.

Schau, C., and Mattern, N. (1997), "Assessing students' connected understanding of statistical relationship," in *The assessment challenges in statistics education*, eds. I. Gal and J. B. Garfield, Amsterdam: IOS, pp. 91-104.

Schau, C., Stevens, J., Dauphinee, T., and Del Vecchio, A. (1995), "The development and validation of the Survey of Attitude toward Statistics," *Educational and Psychological Measurement*, 55, 868-875.

Scott, J. S., and Wisenbaker, J. M. (1994, July), "A multiple method study of student attitude toward statistics," paper presented at the Fourth International Conference on Teaching Statistics, Marrakech, Morocco.

Simon, J. L., and Bruce, P. (1991), "Resampling: a tool for everyday statistical work," *Chance*, 4, 22-32.

Tabachanick, G.B., and Fidell, L. T. (2001), *Using multivariate statistics* (4th ed.), Boston, MA: Allyn & Bacon.

Thompson, A. P., and Smith, L. M. (1982), "Conceptual, computational, and attitudinal correlates of student performance in introductory statistics," *Australian Psychologist*, 17, 191-197.

Uguroglu, M., and Walburg, H. J. (1979), "Motivation and achievement: A quantitative synthesis," *American Educational Research Journal*, 16, 375-389.

Vidal-Madjar, A. (1978), "Teaching mathematics and statistics to adults who are keen on psychology," *Educational Studies in Mathematics*, 9, 381-390.

Velicer, F. W., and Fava, L. J. (1998), "Affects of variable and subject sampling on factor pattern recovery," *Psychological- Methods*, 3(2), 231-251.

Watts, D. G. (1991), "Why introductory statistics is difficult to learn? And what we can do to make it easier?," *The American Statistician*, 45, 290-405.

West, S. G., Fich, J. E., and Curran, P. J. (1995), "Structural equation models with nonnormal variables: problems, and remedies," in *Structural equation modeling: concepts, issues and applications*, ed. R. H. Hoyle, Thousand Oaks, CA: Sage, pp. 56-75.

Wise, S. L. (1985), "The development and validation of a scale measuring attitude toward statistics," *Educational and Psychological Measurement*, 45, 401-405.

Wisenbaker, J. M., and Scott, J. S. (1995, April), "Attitude about statistics and achievement in introductory statistics course," paper presented at the Annual Meeting of the American Educational Research Association, San Francisco, CA.

Wisenbaker, J. M., and Scott, J. S. (1997, March), "Modeling aspects of students’ attitude and achievement in introductory statistics course," paper presented at the Annual Meeting of the American Educational Research Association,
Chicago, IL.

Wisenbaker, J., Nasser, F., and Scott, J. (1998, June), "A multicultural exploration of the interrelation among attitude about and achievement in introductory statistics," paper presented at the Annual Meeting of the International Conference of Teaching Statistics, Singapore.

Wisenbaker, J., Scott, J., and Nasser, F. (2000, August), "Structural equation models relating attitude about and achievement in introductory statistics courses: a comparison of results from U.S. and Israel," paper presented at the Annual Meeting of the International Group for the Psychology of Mathematics Education, Akito, Japan.

Wlodkowski, J. R. (1993), Enhancing adult motivation to learn, A guide to improving instruction and increasing learner achievement. San Francisco: Jossey-Bass.

Wooten, C. T. (1998), "Factors influencing student learning in introductory accounting classes: A comparison of traditional and nontraditional students," Issues Accounting Education, 13, 357-373.

Zeidner, M. (1991), "Statistics and mathematics anxiety in social science students: some interesting parallels," British Journal of Educational Psychology, 61, 319-328.

Fadia M. Nasser
Tel Aviv University and Beit Berl College
School of Education - P.O. Box 26
Ramat Aviv - Tel Aviv
Israel
fadia@post.tau.ac.il