1995

An exploratory study of student attitudes toward statistics and their retention of statistical concepts

Linda Araki

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AN EXPLORATORY STUDY OF STUDENT ATTITUDES TOWARD
STATISTICS AND THEIR RETENTION OF STATISTICAL CONCEPTS

A Thesis
Presented to the
Faculty of
California State University,
San Bernardino

In Partial Fulfillment
of the Requirements for the Degree
Master of Science
in
Industrial/Organizational Psychology

by
Linda Araki
June 1995
ABSTRACT

An assessment of the statistical knowledge of psychology students taking psychology laboratory courses (beginning lab and advanced sub-specialties -- e.g. lifespan, experimental, I/O) was conducted. The students completed at least one course in Psychological Statistics as a prerequisite to taking the psychology lab course. The predictor variables of age, gender, lab experience, statistics course grade, repeating statistics course, attitude towards statistics, location of statistical training, and time since introductory statistics course(s) were tested for their predictive value on the criterion of overall statistical comprehension via the Statistical Competency Survey (SCS) developed by the researchers. The SCS is composed of 74 conceptual multiple choice questions measuring five statistical domains: basic concepts (BC), descriptive statistics (D), correlation/regression (C/R), hypothesis testing (H/O), and inferential statistics (I). The 118 students also completed Wise's (1985) Attitude Toward Statistics (ATS) survey. Of the predictor variables noted above, only the ATS score and location of statistical training entered the stepwise multiple regression equation and thus were the only significant predictors of overall performance on the SCS. The only statistically significant difference between men and women was found in the C/R
subscale of the SCS, with men scoring significantly better than women. Therefore, support for gender differences in statistical comprehension appeared to be weak at best. These results are discussed in terms of developing future evaluation and outcomes assessment measures for the psychology major.
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INTRODUCTION

The current trend of increasing enrollment that has impacted the limited financial resources of public and private universities, has made the availability of programs and the quality of educational programs important factors in the accountability of educational institutions (Wolff, 1992). Recently, the Advisory Committee to the California State University system attempted to satisfy this demand by adopting an outcomes assessment policy bolstering the need for assessment procedures to be evaluated on the student level and be student-centered (Arcininiega, White-Loewry, Young, Blue, Nyberg, Goldstein, Williams-Burger, Richardson, Loyd-Casanova, & Weber, 1989). Therefore, the requirements and competencies of the numerous academic departments within the California State University system -- e.g., psychology, biology, mathematics, engineering -- may serve as criteria to evaluate the educational quality of these respective departments. This study will focus on the statistical competencies required of students for completion of the baccalaureate degree in psychology at California State University San Bernardino.

Students who seek degrees in liberal arts programs are often required to complete a statistics course, which frequently contrasted the reason why they selected their major (R. Warden, personal communication, May 6, 1994).
Research has found that psychology students in introductory statistics have higher math anxiety that math students in math courses (Elmore & Vasu, 1980c). The anxiety of these students maybe generated by pressure to pass core statistic courses which are designed to distinguish the minimally competent students (Fenster, 1992). Many authorities in statistics attribute the difficulty in learning statistics to the individual's lack of practice in critical thinking and mathematical training (Elmore & Vasu, 1979a).

Statement of Purpose

The purpose of this exploratory research was to investigate the potential factors (i.e. gender, time lapse between the latest statistics class and completion of the statistics test, grade point average (GPA), attitude towards statistics), which are associated with the comprehension and retention of statistical knowledge in Baccalaureate Psychology students. The criterion variable was statistical competency, which was measured in five subdomains: basic concepts, descriptives, correlation/regression, hypothesis testing, and inferential statistics.

Since the definition of statistical competency is not standardized within the Psychology department at CSUSB (M.L. Riggs, personal communication, April 19, 1994), it was necessary to develop an assessment instrument. The Statistical Competency Survey (SCS) was constructed to
measure the depth of statistical comprehension in students. A conceptual question format as suggested by the 1988 article by McMillan, allows the opportunity for students to analyze and synthesize their knowledge instead of simply recalling formulae. In this study, the students attitudes toward statistics and their level of statistical mastery was evaluated via a set of working hypotheses listed on pages 30-32. The researcher examined the information that the students disclosed (i.e., attitude, time since last course in statistics, instructor, type of institution) for predictor variables that may have attributed to the statistical knowledge of the students.
THE HISTORY OF ASSESSMENT

Assessment is not new to higher education. Historically, the theological basis behind assessment emerged in the realm of higher education -- from the researchers (e.g. Henry A. Murray) at the Harvard Psychological Clinic in the 1930's, who were appraising the presence of personality characteristics (Hartle, Harris, Ewell, Jones, Loackeret, Elman & Lynton, 1988).

The traditional definition of assessment by MacKinnon in 1975 was cited by Hartle et al. (1988):

A method for the psychological evaluation of individuals that involves the examination and observation of individuals in a group by a number of assessors who administer a multiplicity of tests and procedures. Following the aggregation of test scores and subjective impressions, the assessors formulate psychodynamic descriptions of the assessed subjects that can be used for the prediction of behaviors in certain roles and situations (p. 2).

In higher education, it has been difficult to apply assessment procedures in this fashion, so consequently Hartle et al. (1988) listed five variations of the term "assessment" which demonstrated that a gamut of approaches have been used to improve educational quality. Assessment has be done by: using multiple measures and observers to track intellectual and personal growth of the individual over time; measuring the student’s performance in pre-tests and post-tests to evaluate the student's contribution to the
academic program; using standardized tests to measure general or specific knowledge; measuring the accountability of the institution; and assessing student attitudes and values. This research will refer to assessment as "outcomes assessment (OA)" and comply to Halpern's (1987) definition which is: "the measurement of how much an individual or group has learned from higher education." (p.6).

Fervent concern for the measurement of the ability levels of college students coincided with the expansion periods in the 1930's and 1940's, in which the amount of eligible students applying for colleges and the average size of the institutions grew rapidly (Resnick & Goulden, 1987). Consequently, this phenomena pressured institutions to diversify their academic programs, hire more instructors, and offer additional courses and majors (Resnick & Goulden, 1987). The issue of equal opportunity and student access to higher education soon diminished in importance after educational productivity became a major issue in the 1980's and 1990's as the result of the shrinking budgets of educational institutions (Hartle et al., 1988)

Are college students being educated? This is the new issue faced by the educational institutions of today. Though OA has been conducted in different levels of the educational system, the growing interest to better measure
student abilities appeared evident in past and present assessment approaches.

The traditionally used approaches to OA were discussed in the literature by Astin (1982): 1) **Nihilist view** - doubts the validity of the OA models. Therefore, no quality judgements are feasible because achieving valid assessments in collegiate programs are unrealistic. 2) **Reputational measures** - The measures used in evaluation are selected according to the consensus of stakeholders’ (e.g., administrators, faculty, students, parents, taxpayers) opinions of what is representative of the institution. 3) **Resource measures** - The quality of the recruited staff and students is evaluated instead of the quality of learning obtained by the current students (e.g., highly trained and prestigious faculty members and bright students are used as indicators of success). 4) **Outcome measures** - The quality of the students admitted to the program is measured as an outcome measure (e.g., diagnostic entry test) rather than the program itself which can be aggregated with other information (e.g. certificate programs) so that revised or alternate programs are created. Otherwise the diagnostic test can serve in a gateway model as a measure of basic competencies which must be met before acceptance to a program. 5) **Value-added measures** - are outcome measures that are sensitive to improvements in the educational program.
Boyer and Ewell (1988) defined value-added measures as how much of the students' abilities are attributable to their undergraduate education.

The most common use of assessment in American higher education has been to evaluate the effectiveness of undergraduate programs. According to Resnick and Goulden (1987), institutions have suffered the consequences for prioritizing the recruitment of qualified students, instead of monitoring and improving the quality of the students in the institution. The focus on recruitment versus instruction has been costly. Large numbers of poorly qualified and poorly educated students have been graduating from institutions of higher education. So, two major concerns in OA have been highlighted by Resnick and Goulden (1987): 1) the multitude of subdisciplines from every major field of inquiry, and 2) the growing dependency on limited public funding.

Systematic evaluations of assessment implementation have been emerging in response to the predicament in educational institutions. The assessment study published by the California State University (CSU) system clarified that OA done in the 1980's and the 1990's had focused on different issues which were influenced by the availability of funding and community support (Wolff, 1992). In the 1980's, the universities benefitted from the financial
generosity of the public and private sectors who sponsored innovation, experimentation, and assessment activities. In contrast, the funding situation in the 1990's has required careful integration of assessment into existing teaching and learning activities at the departmental and classroom levels (Wolff, 1992). So, financial generosity toward "add-on" activities like assessment of the 1980's has dissipated (Ewell, 1992). The revised mandates of mainstream universities (e.g. California State University system) suggest that traditional assessment efforts must adapt to penurious budgets and integrate assessment activities into the planning of the departments and classrooms to conserve on time and labor (Ewell, 1992).

Outcomes Assessment (OA)

OA in higher education has typically measured the quality of education directly by measuring the amount of learning achieved by students instead of the common indirect variables available such as research reputation and size, opinion surveys, size of library, and retention rates (Halpern, 1987).

The assessment procedures of educational institutions have existed for some time, however the variables that quantify the quality of education have been revised. The past measurement of the educational quality of an institution succeeded in describing the institution and/or
the student, however the measurement of quality educational services in the past was not a priority (Resnick & Goulden, 1987; Wolfe, 1992).

In OA, individual and group differences are measured according to: an individual's knowledge (cognition), skills (ability to apply knowledge), attitudes and values (structure and integration of personal values) and behaviors. These differences can be assessed by various methods (i.e., standardized test scores, opinion surveys, interviews, and biodata) and then analyzed.

Understanding the primary use of such data continues to requires planning. To determine the primary use of data, Halpern (1987) suggests focusing on four deliberate questions: 1) What do I want to know and why?; 2) What should be measured and how?; 3) Does the method really reflect what is meant by quality?; 4) Does it enhance the quality of service in higher education?. Then the appropriate model and methodology needs to be discussed.

Halpern (1987, 1988) organized the assorted assessment approaches and data in OA into the following models: 1) The Budget Decisions/Accountability model which uses data (e.g., the prestige the institution, quality of students and teachers, availability of educational resources, amount of knowledge learned) to assist the educational stakeholders (taxpayers and parents) on deciding if the institution is
cost efficient and maintaining its educational quality. 2) The Gatekeeping functions model, screens students through mastery tests in which a set score must be met to verify basic academic competencies. Although this model is very appealing to higher education institutions, the screening tools may eliminate large numbers of potential candidates from under-represented ethnic groups. A remedy suggested by Banta and Fisher (1988) is the use of peer reviews along with gatekeeping to reduce the adverse impact of the decisions that are made. 3) The Program improvement model requires that faculty and administrators continually collect individual and group data, such as grades. This data enables individuals to be given feedback on their academic progress. Collectively, this same data can be used to develop programs. The procedures used are diagnostic tests and exit tests. This model is appealing because the faculty are actively supporting changes leading to greater satisfaction of students and improved retention rates.

After a model has been chosen, the appropriate assessment methods need to be selected. Caution should be exercised regarding the appropriateness of the test content, the suitability of information for public disclosure, and if there are enough funds to operate the assessment methods. Some methods may or may not be currently used (in some level) at the educational institutions. To measure student
abilities, the testing methods available are: 1) **Standardized testing** - is easily administrated and the least subjective method. 2) **Comprehensive examinations** - are mastery tests of core concept. 3) **Individual assessment** - is evaluating individuals on a number of skills (i.e., interviews and performance tasks) by a group of assessors so multiple evaluation of student performance is obtained. 4) **Surveys** - Inexpensive, flexible, and efficient, however the information is indirect and there is a potential lack of response; 5) **Tracking** - is maintaining a record of the individuals performance and behavior over time (Halpern, 1987).

Specifically, the previous testing procedures can be applied singularly or in combinations in the following three ways to measure assessment in educational institutions (Hartle et al., 1988): 1) To measure student skills as part of the admissions/placement procedure. 2) To measure student skills to determine if standards are met so that the individual can advance to the next level. 3) To measure student skill to determine if the individual is prepared to graduate.

In sum, OA procedures enable higher education institutions a method to quantify the knowledge, skills, and abilities of alumni and current students. The key to OA is to organize the procedure(s) around the vision and purpose
of the institution, therefore the model used should fit the nature of the institute itself. The information desired and how to obtain it is important in selecting the appropriate model and methodology to use. Given the limitations of the selected model, certain testing methods are suggested to best obtain the data that is appropriate to be assessed.

Since the faculty is utilized in collecting the OA data -- which influences important academic decision -- the current favorable attitude of faculty to OA is important to maintain objectivity and a successful OA program (Riggs & Worthley, 1992).

Finally, OA has been endorsed by the CSU system (Wolff, 1992). The assessment tool used in the present research can be used as a standardized test that can collect personal data and measure statistical competency in the Halpern program improvement model. The Halpern program improvement model would benefit the CSUSB Psychology Department by assessing the quality (past, present, and future) of the curriculum of the Psychology Department and the progress of the CSUSB Psychology students. Moreover, the reputation of the Psychology Department and the CSUSB students should benefit from the increased caliber of education as baccalaureate students compete for graduate programs in Psychology.
The Practicality Of Outcomes Assessment (OA)

There are very practical reasons to implement OA programs in higher education. OA allows the educational institution to be aware of the "quality" of students before, during, and after their training in the numerous disciplines and subdisciplines of the departments. Consider the implications regarding the quality of students that were highlighted by Astin (1982): 1) Enrollment has stabilized; 2) Public support has declined; and 3) Quality students and prestigious faculty are limited. Intuitively, the resulting situation has a number of colleges vying for scarce resources (quality students and faculty) to maintain their educational services and products. As a result, the accountability, quality, and availability of educational services and products -- i.e., the undergraduate and graduate programs -- grows increasingly important to the public (Astin, 1982).

Astin (1982) also discussed the practical use of OA as an evaluative tool. The use of assessment allows the educational institutions to measure educational productivity. In measuring educational productivity, variables such as the number of graduates with advanced degree, and income of alumni, are "outcome measures" that fail to describe the extent of educational impact or effectiveness of educational institutions. Astin added that
when outcome measures are selected, outside influences that impact the validity of outcome measures need to be considered (i.e., Ph.D. impacted by sex, student ability, field of emphasis) -- do not make inferences from single factors. Large samples are desired in determining educational productivity so the use of longitudinal student and institutional data increases our understanding of the educational process although limitations exist from the college environment (Astin, 1982).

A recent survey of graduate programs in North America revealed additional public concerns on the educational productivity of undergraduate training (Aiken, West, Sechrest, & Reno, 1990). The competency of graduate training in statistics, methodology, and measurement in Psychology was labeled as deficient. Requiring that undergraduate programs strengthen their mathematics and statistics training was suggested as a potential strategy to increase competence in these critical areas (Aiken et al, 1990). To strengthen the existing statistical training in the undergraduate psychology departments, it is important to determine the level of mastery of undergraduates and to set academic standards for the Psychology Department. OA approaches then need to be focused on detailed analyses and specific accountability of student mastery, which will probably be collected predominantly by the teaching faculty.
Education institutions have incorporated strategies to improve the quality of education, which include the expansion of assessment procedures. The CSU assessment study recommended addressing improvements in teaching, communications between and about students, and the quality of assessment. Specifically, recommendations were to be applied at the student, department, campus, and system levels. Applied at a student level, Krueger and Heisserer (1987) stated that a comprehensive assessment program informs, enlightens, and becomes a basis for action. When put to work, OA involves every level and segment of the organization. Thus, a well planned and accurate OA can result in a powerful tool for the enhancement of teaching, learning, and institutional effectiveness policies (Halpern, 1988).

Finally, there is evidence that systematic OA programs have been successful. For example, the systematic OA program at University of Tennessee Knoxville (UTK) which began in 1982, has formed an impressive list of achievements (Banta & Fisher, 1988): The team of administrators in the Academic Program Review benefits expressed appreciation for the survey responses and comprehensive test scores from the OA, which gave them student performance oriented data to add to the pre-existing university oriented data (i.e.,
operating budgets, faculty credentials, size of the library collection and the abilities of incoming students).

Improvements in enrollment and marketing, faculty and staff, equipment replacement, as well as program enrichment or reductions were made involving the consideration of student needs at UTK.

The decisions that resulted from this student oriented data were well received by faculty and students. Increased student advisement and interaction with instructors elicited a positive response from the students, who were able to clarify information and student expectations (Banta & Fisher, 1988). Students openly accepted the use of comprehensive exams to help students grow to master the core competencies in the program and department. The impact of faculty involvement was vital to the OA process, for the faculty discovered new insights regarding the department curriculum that enabled them to develop core competencies for all students and more effective methods of teaching (Banta & Fisher, 1988).

Thus, the implementation of assessment programs continue to grow and become increasingly practical. Educational institutions using OA have a means of measuring the quality of both current and potential students in addition to alumni during a time when there is less money and staff available for high quality education.
programs must also become creative with limited budget and control costs by incorporating OA into instruction instead of adding on to existing practices (Ewell, 1992). Assessment programs can gather the information demanded for the accountability and quality of educational services. For example, after reviewing the successes and failures of OA, the advisory committee to the CSU system has recommended OA be used to address improvements needed in teaching, in communication between and about students, and in the quality assessment on student, department, and system levels (Goldstein, 1989; Wolff, 1992).

Caveats of Outcomes Assessment

While, the current educational and political atmosphere is favorable toward assessment, there are a few disadvantages that are associated with the testing component of assessment. Darling-Hammond (1988) was critical of the potential problem of using test inappropriately. Schools do not take tests; students do and they take their test scores with them as they enroll in subsequent institutions. Moreover, the score of an institution is not the appropriate unit of measure. Thus Darling-Hammond (1988) warns that: 1) You cannot compare the average scores of one student population to a different student population and infer the cumulative educational progress of an institution. 2) Focus on the distribution of resources and the quality of
education instead of the distribution of test scores. 3) Measures need to be complex, involving real observations, judgements by teacher and administrators regarding what to learn and how learning is determined. 4) Be aware of side effects (i.e., test scores increase instead of learning, wrong analysis, student equity) because regardless of the assessment approaches used, the public will hold the institution accountable for educational accomplishments and mistakes.

Halpern (1987) shared similar concerns regarding the circumstances behind assessment and suggested the following recommendations to minimize side effects: 1) Use multiple methods and not single tests. It is suggested to combine a normed instrument (e.g., ACT), examinations by faculty (e.g., senior comprehensive exams), and available measures kept by the institutional research offices (e.g., GPA). 2) Get the faculty involved, for their support is essential for success. 3) If performance based funding is used, it works best if the revenue is additional funds, otherwise conflicts over resources may occur. 4) Use OA for program decisions, not retention or tenure decisions -- helps maintain goodwill between faculty and administration. 5) Use the type of data collection that matches the vision of the institution or department (e.g. The research institution records the number of published articles). 6) Use valued-added (talent
development) measures that emphasize educational gains instead of exit data such as GREs. 7) OA designs needs to be well coordinated and planned. 8) Obtain the needed finance for OA, for costs are unavoidable.

A final caveat according to the accrediting commission officials is to be cautious not to set outcome definitions too narrow and the misuse of instruments to measure competence (Thrash, 1988). Thrash (1988) pointed out a few cautions: 1) Display caution in overemphasizing student achievement for it may result in the reduced quality of life for students. 2) Institutions may base their OA procedures without considering the situational nature of the process. 3) The faculty would begin "teaching to the test" (Darling-Hammond, 1988; Thrash, 1988). 4) Although accrediting commissions use student achievement in their assessment measures to determine educational achievement, they are concerned that overemphasis on student achievement will have a negative side-effect on the national commitment to access equity for individuals seeking a college education (Thrash, 1988).

The practice of OA has been utilized since the population of college bound students increased dramatically about sixty years ago. Since then, OA has been both praised and criticized. OA is currently touted as an important activity to secure evidence for the effectiveness of
educational programs. Halpern has suggested that clear and realistic goals are set initially for the institution so that the appropriate OA model can be selected so that correct data gathering procedures are used. Careful planning and securing cooperation among stakeholders (e.g., instructor and administrators) has been vital to the success of past OA programs and the improvement of college programs. The purpose of the outcome data plays a critical role in the degree of acceptance among administrators, instructors, and students involved in OA programs. Critics fear that the information learned in OA will be misused. However, the current academic atmosphere is favorable to OA. The information from OA has been effective and has provided strong evidence for the educational gains of the student(s) at nationwide colleges very effectively.
THE ASSESSMENT OF ATTITUDES TOWARD STATISTICS

Math anxiety has been defined as "an anxious state induced by fear of failing when attempting to learn or to demonstrates one's learning of mathematics" (Handler, 1990, p.20). Handler (1990) addressed the issue of math anxiety, cultivating plausible "mathematical illiteracy" in adults. Adults who have various educational and occupational backgrounds have been experiencing math anxiety in daily math and statistics encounters such as: standard computations, graphs, probabilities, and quality control statistics (Handler, 1990).

Statistics, according to the Webster New World Dictionary (1986), are numerical facts or data which are assembled, classified and tabulated to present significant information about a given subject. Statistics involves the application of mathematical skills and concept of logic. Statistical literacy encourages problem solving and critical thinking skills, which are highly desired by employers (Fenster, 1992).

A negative attitude toward statistics seems to prevail among many college students who have inadequate mathematical background and perceive statistics as too complex and abstract (Elmore & Vasu, 1979a; Fenster, 1992; Wise, 1985). Bleyer (1979) found a negative attitude toward mathematics existed among students in different types of educational
institutions (e.g., state universities, technical colleges, and community colleges). Melvin and Huff (1992) remarked that "Although the first course in statistics is high on the list of courses preferred by graduate schools, many undergraduates face it with trepidation" (p. 177).

According to Wise (1985), the negative attitudes toward statistics has impeded students in learning statistics. Furthermore, Wise (1985) stated that the instructors of introductory statistics courses perceive "an implicit course objective is to foster appreciation of the subject matter, through development of more positive attitudes of the students toward the use of statistics in their fields of study" (p. 401).

This anxiety that imbues so many Psychology students that the teaching of statistics and its impact in the psychology curriculum was discussed at a symposium at the 1995 Western Psychological Association convention in Los Angeles. The opposing viewpoint, which was held by Frederick Meeker Ph.D. who served as chair, supplemented his viewpoint with an essay; Statistics: why we can’t know it. Given that some students (mono-brained) cannot learn statistics, than an alternate tools needs to be recommended in lieu of statistics as it is currently taught in the Psychology curriculum (Meeker, 1995). However, the remaining four Ph.Ds participants (Allen, M.J., Berger,
D.E., Miller, R., & Quesnell, D.) argued that the requirement of statistic courses in Psychology programs should continue despite the debate on statistical testing. Teaching statistic courses in an applied approach that matches learning style to one's personal schema, was highly recommended so that learning statistics is facilitated.

So, the requirement of statistics course work for undergraduate and graduate degrees continues to grow (Fenster, 1992). According to Jannarone (1986), poor statistics preparation leads to student anxiety which is detrimental. His research found that: 1) The poorly prepared students who entered graduate programs were at high risk of dropping out. 2) It was difficult to teach advanced statistics simultaneously to students who failed to master basic statistics and the students who mastered basic statistics. 3) The lack of quantitative skills was detrimental to the morale and academic progress of minority groups.

Ware and Chastain (1992) stated that facilitating learning in statistic courses has been challenging and that relevant skills, teaching strategies, and personality traits have remained elusive. The most demanding challenge is to find cognitive and motivational factors that can increase performance of poorly prepared students. Therefore, the current study sought to elaborate on the content of
statistical achievement of Psychology students and its potential applications in learning and assessment procedures.

The Predictors of Statistical Achievement

Extensive work has been done by Patricia Elmore and her associates studying the factors associated with statistical achievement. Elmore (1979) used a multiple regression analysis to develop a statistical achievement model based on the following variables: statistical achievement, attitudes toward mathematics-related courses, previous mathematics courses, sex, spatial visualization ability, and masculinity-femininity of interest pattern. The sex role and spatial visualization ability were found to be significantly related to success in statistics. Elmore and Vasu (1986) found that when comparing women versus men, women had lower scores in spatial ability, lower quantitative GRE subscale scores, and less college math courses. Yet the women overcame their lesser abilities (in comparison with men) and achieved higher total number of points in the statistics course than the men -- which was attributed to their scores on the attitude toward feminist issues factor. These women, who scored themselves as more liberal, were well motivated and success oriented. Her recent work found that students who were taught statistics with the use of computers would have increased positive attitudes towards computers and
decreased statistical anxiety (Elmore, Lewis, & Bay, 1993).

Bleyer (1979) found that college students over 23 years old had a more positive attitude toward mathematics than the students 23 or younger. Another finding was that the students attending university or technical schools had a predominantly negative attitude toward mathematics than the students at community colleges.

So the list of predictor variables for the success of individuals in statistics have become extensive. Computer related variables have become recent additions to the set of statistical achievement predictors (Elmore et al., 1993). The variables studied in research which were cited by Elmore et al. (1993) have been: previous courses in math, statistics, and computer science; attitudes toward statistics; mathematics ability on statistics achievement; math anxiety; attitude toward computers; mathematical background; age; sex and gender interest; spatial visualization ability; and other academic and personal characteristics - cumulative grade point average (GPA), Graduate Records Examination (GRE), Veteran status, race and major field of study.

Some of the factors have been inconsistent. The research has been unclear on gender difference, which Elmore and Vasu (1986) believed was the result of inconsistent definitions of mathematical ability and the fact that the
majority of past data was obtained from children and adolescents instead of college students. In contrast, the most stable predictors have been the individual's attitude and background toward mathematics; spatial visualization ability; and grade point average. The success of undergraduate students in statistics courses was not influenced by the student's history of mathematics; instead, the overall academic ability of the student set the pattern of grade distributions, in which high achievers had the highest grades and the low achievers had the poorest grades (Giambra, 1970). Current research has continued to find that students with high GPA do well in statistics (Ware & Chastain, 1991).
A GENERAL SUMMARY

If the Psychology Department were to caucus on the vision and direction of teaching within the department, it is plausible that the exchange of information could warrant grounds for an OA project. The gathering of personal data and desired level of statistical competency for Baccalaureate candidates could be evaluated via the Halpern program improvement model to assess the quality of the CSUSB Psychology Department and the progress of the Psychology students at CSUSB.

It should be reiterated that a cooperative and amicable campus environment can increase the likelihood of an effective OA program. It is important to maintain: clearly defined objectives; systematic and multivariate data; the reliable assessment procedures; foster good-will among administrators, faculty, and students; and be alert to adverse impact to under-represented groups.

Careful organization of OA remains essential for the educational institutions who are still on limited budgets and time (i.e., UTK and the CSU system). For institutions using OA program(s), integrating OA as a part of the institution's instructional programs has made the shortage of funds and time a little easier for the campus(es) to bear (Ewell, 1992). The level of success is deeply seeded in the political good-will of the stakeholders involved, especially
between administrators (decision makers) and faculty (data collectors). In addition, measurement issues of reliability and validity cannot be ignored and must possess adequate psychometric properties otherwise important decisions will be based on faulty measurement (Riggs & Worthley, 1992). Test fairness (and unfairness) can surface as a "side-effect" so creative indices and combination of more than one index needs to be used to minimized adverse impact (Riggs & Worthley, 1992).

Wolff (1992) argued that the only legitimate purpose of assessing student OA is to improve teaching, learning, and academic advising at the individual course program and institutional levels. Although the exploratory nature of this thesis project has been limited to the standardized administration of a survey and test, it is anticipated that quantifying the level of student knowledge in required classes such as statistics, will be useful in beginning potential OA models to use in the Psychology Department at California State University, San Bernardino (CSUSB).

An introductory statistics course is required for the completion of the baccalaureate degree in Psychology. The introductory statistics course, or its equivalent, is stated as a prerequisite for enrollment in the beginning (Psy 311) and advanced (Psy 430s) experimental psychology laboratory classes in the California State University San Bernardino.
Bulletin (1993-1994). The statistical techniques taught in statistics courses have been used as tools in research and in the breakthrough of new ideas (Elmore & Vasu, 1979b). Thus, the statistical competency, especially if there is a deficit in skills, has important implications.

Research has indicated attitudes towards statistics (i.e., negative attitudes and anxiety affect performance levels), mathematical and statistical background, and overall GPA as the most consistent predictors for statistical success (Elmore et al., 1979a, 1986, 1993; Ware & Chastain, 1991). According to Elmore and Vasu (1980b), "A number of authorities in statistics suggest that the difficulties encountered by many students enrolled in courses in statistical methods may be attributed to lack of practice in precise and rigorous thinking and to inadequate mathematical training" (p. 1).
HYPOTHESES

Ten hypotheses were developed based on the review of the literature. Seven hypotheses were derived from the conceptual portion of the survey and three hypotheses were derived from the attitudinal portion of the survey.

1. The harmonic mean of basic statistical concepts and descriptive statistics is expected to be higher than the harmonic mean of hypothesis testing, regression/correlation, and inferential statistics. Basic concepts and descriptive are used more often and uniformly discussed in class more than the other three areas.

2. The student's grade in their statistics course will be negatively correlated with attitude. Given that the nature of the grade scale and attitudinal scales are scored in opposite directions, a negative relationship is expected. Receiving high grades are a natural reinforcement to continue learning more about statistics.

3. There will be no relationship between age and score on the scales. Statistical experience is not necessarily measured in calendar years so this combination of variables is not expected to be better than chance or it may be affected by moderator variables.
4. Attitude toward statistics will be negatively correlated with the student's overall statistical competency score. Conversely, the more positive the attitude toward statistics, the higher the students overall score on the test.

5. The advanced lab students are expected to have higher mean scores than the beginning lab students. Lab experience would involve applying statistical concepts and investigating the resulting implications. Therefore, the advanced lab students should perform better than the beginning lab students (Psy 311).

6. CSUSB students are expected to have higher means than students who took statistics at two year colleges and other four year colleges.

7. The students who took statistics most recently will have higher mean scores than the others students. The time between the statistics class and taking the survey will be measured in months. The memory of an individual is affected by the amount of time between learning and recalling the information.

8. High achievers in statistics are expected to score higher on the SCS than the low achievers in statistics. A positive relation is expected between score in statistics course grade and the score on SCS scales.
The student's gender was expected to predict statistical proficiency on the SCS conceptual questions, specifically according to hypotheses 9 and 10.

9. **Men will have higher mean scores than women on the each of the five conceptual factors.** Although gender studies remain inconsistent, the men are expected to do better on the test because the motivational advantage the women experienced found in the Elmore and Vasu (1986) is unlikely in this "one time administration of this test."

10. **Men will have a more positive attitude toward statistics than women.** The cultural treatment of men often encourages them to be more analytical thus statistics would seem less threatening than for women.
PROPOSED MODEL

A multiple regression model will be used to ascertain the usefulness of the predictor variables proposed for this current study: sex; age; time (period of months since recent statistics course); statistical training at CSUSB versus elsewhere; psychology lab experience; Wise ATS score (degree of positive or negative attitude); and course grade (grade in statistics class). The dependent variables were the total SCS score (statistical proficiency) and the subscores (basic concepts, descriptives, correlations/regression, hypothesis testing and inferential statistics). Two additional group mean comparisons were used comparing SCS subdomains (harmonic mean comparison) and gender difference. An additional correlational study was used for evaluating the relationship between Wise ATS score and course grade.
Subjects

A baseline study was conducted with 16 students without statistical experience and 24 students who were graduate students and had completed their undergraduate and graduate statistics requirements. One of the students without statistical experience had limited comprehension of English so her data was deleted. The low baseline study was done during Summer term 1994 and the high baseline study was done during Spring term 1994. The subjects were asked to volunteer indirectly through instructors at California State University San Bernardino (CSUSB). The descriptives are found on Table 1. The final group of 15 students without statistical experience had 20% sophomores, 26.7% juniors, 40% seniors, and 13.3% graduate students. The average age was 27.5 years old. Women comprised 70.8% of the group and men comprised 29.2% of the group. The 24 students with past statistical experience averaged 27.3 years old and there were 13% seniors and 87% graduate students. Women comprised 75% of the high baseline membership versus the men who comprised remaining 25% of the group membership.

The subjects in the primary study were 120 psychology lab students taking the introductory experimental psychology course (Psy 311) or an advanced laboratory course (Psy 430s) in Spring term 1994, at CSUSB. A listing of the
descriptives of the sample population is found in Table 1. Two of the original 120 subjects changed their mind and their results were deleted from the study. The average age of the 118 remaining subjects in the primary study was 27.8 years old. Women comprised 73.7 percent of the subjects and men comprised 26.3 percent of the subjects.

**Procedures**

The convenience sample for the primary study was formed by soliciting subjects through the instructors of the Psy 311 and Psy 430s prior to the Spring term 1994. The participants completed the research instrument during their first or second class meeting according to the stipulations of the instructors. The participation in the project was voluntary and extra credit was offered at the instructors' discretion. Administration of the test was conducted before students had reviewed statistics in class.

The test administration for the primary and baseline study groups, was conducted using standardized instructions which have been included as Appendix A and B. An oral consent was read followed by the proctor reading the instruction aloud while the participants read along. Once the survey was returned each subject was required to read the debriefing form and sign an extra credit form if applicable. Copies of the Oral Consent, Debriefing Form, and Statistical Competency Survey (SCS) are included as
Table 1.
Descriptive Statistics of the Baseline and Primary Samples

### BASELINE STUDY - LOW BASELINE

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### PRIMARY STUDY

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<td>C</td>
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<tr>
<td>CSUSB</td>
<td>15 55.6</td>
<td>42 53.8</td>
<td>57 54.0</td>
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<td>48 46.0</td>
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<tr>
<td>Under 12</td>
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<td>12 17.5</td>
<td>18 20.4</td>
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<tr>
<td>Over 12</td>
<td>4 19.0</td>
<td>27 39.1</td>
<td>31 35.2</td>
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<tr>
<td>Over 24</td>
<td>5 23.8</td>
<td>27 39.1</td>
<td>32 35.4</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Over 60</td>
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<td>3 4.3</td>
<td>5 6.0</td>
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<td>Over 120</td>
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<td>2 3.0</td>
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**Note:** 
- $^a$n = 15, $\bar{u}$ = 27.5. 
- $^b$n = 24. 
- $^c$n = 23. 
- $^g$n = 19. 
- $^s$Group (n = 118; $\bar{u}$ = 27.82; S.D. = 7.51): Male ($\bar{u}$ = 26.16; S.D. = 5.59); Female ($\bar{u}$ = 28.41; S.D. = 7.98). 
- $^t$Male n = 31; Female n = 87. 
- $^w$Group (n = 106) $\bar{u}$ = 3.84 S.D. = 2.17; Male (n = 27) $\bar{u}$ = 4.00 S.D. = 2.37; Female (n=79) $\bar{u}$ = 3.78 S.D. = 2.10. 
- $^y$Group (n = 90) $\bar{u}$ = 25.10; Males (n = 21) $\bar{u}$ = 34.39; Females (n = 69) $\bar{u}$ = 22.27.
Appendix C, D and E respectively.

**Measures**

An assessment tool was developed to measure the statistical comprehension of psychology students, to survey their attitudes toward statistics, and to collect personal demographic information (e.g., sex, age). The statistical comprehension instrument developed for the study, which is titled Statistical Comprehension Survey (SCS), has 74 conceptual questions measuring statistical knowledge on five domains listed below. The 20 item field subscale from the Wise (1985) Attitudes Toward Statistics scale was used to measure psychological attitudes toward statistics.

In order to develop the conceptual portion of the research instrument, a pool of statistical questions was gathered from three subject matter experts with a Ph.D. in Psychology who have taught Psychological Statistics. The pool of questions were gleaned to 74 items. Five rationale content domains were represented: Basic Concepts (BC), Correlation/Regression (C/R), Descriptive Statistics (D), Hypothesis Testing (H0), and Inferential Statistics (I). The 74 items became part A on the test and the test specifications explaining the criteria of the content domains are found in Appendix F.

**Wise's Attitude Toward Statistics Scale (ATS)**

To complete the research instrument, an attitudinal
measure was included to address the affective component that may attribute to the students' statistical competency. The Attitudes Toward Statistics Scale (ATS) by Wise (1985) is comprised of two subscale; the 20 item attitude toward the field of statistics (scale α reliability = .92) and the nine item attitude toward the course (scale α reliability = .90). The attitude toward the field of statistics subscale was inserted as part B of the research instrument. In this study, since the course was not the focus of research, attitude toward the statistical course was not used. The 20 items in the field scale used a likert response format (five point interval from strongly agree to strongly disagree). The reliability of the scale (scale M = 46.58, s.d.= 12.48, scale α reliability = .92) from the primary group was comparable to previous ATS college student scores on the attitude toward the field of statistics scale (Elmore et al. 1993; Viswanthan, 1993; Wise, 1985).

Analyses

An item analysis of Part A of the SCS instrument was completed to evaluate the difficulty of the items (a mean p-level of .50 was desirable). The inter-rater reliability of scale dimensions (95% agreement) was completed by two SME's who performed a "Q-sort" in which the questions are sorted into the five content domains: Basic Concepts, Correlation/Regression, Descriptive Statistics, Hypothesis
Testing, and Inferential Statistics. Reliability analysis for the ATS scale in Part B was also completed.

Each of the 10 hypotheses were tested using the general linear model and the individual tests have been listed in the subsequent table which included: a priori comparison of group harmonic means (Hypothesis 1); a multiple regression analysis of 7 predictors and the SCS score(s) as the criterion (Hypotheses 3 - 8); 1 Pearson correlation (Hypothesis 2) and 2 additional t-tests (Hypotheses 9 and 10). (See Table 2).

The research used traditional variables used in prior studies (Bleyer, 1979; Elmore & Vasu, 1979; Fenster, 1992; Giambara, 1970): sex; age; time (amount of months since recent statistics course); grade in statistics course; and Wise’s ATS score (degree of positive or negative attitude). In addition to the traditional variables, statistical experience was examined as statistical training at CSUSB and Psychology Lab experience. The set of Statistical Competency Survey scores was used as the dependent variable (statistical proficiency). These variables were assessed in a series of regression equations for their impact in the prediction of the statistical abilities of Psychology Students.
### Table 2

**Statistical Analyses for Working Hypotheses 1 through 10.**

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<th>Variable two</th>
<th>Analysis</th>
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<td>1</td>
<td>BC, D</td>
<td>C/R, H0, I</td>
<td>A Priori t-test (1,2) vs (3,4,5)</td>
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<td>2</td>
<td>Course grade</td>
<td>ATS score</td>
<td>Pearson r</td>
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<td>Total SCS score</td>
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<td>Regression</td>
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<td></td>
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<td>Regression</td>
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<td>Time</td>
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<td>*</td>
<td>Sex</td>
<td>Total SCS score</td>
<td>Regression</td>
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*See Additional Hypotheses 9 and 10

### Additional

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<th>Hypothesis</th>
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<td>9</td>
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<td>SCS Scores</td>
<td>t-test</td>
</tr>
<tr>
<td>10</td>
<td>Sex</td>
<td>ATS Score</td>
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RESULTS

Prescreening of Data

The data were screened for normality (skewness $z < 3.0$, $p = .001$; kurtosis $z < 3.0$, $p = .001$), to assess the fit of the data set to the assumptions of statistical analyses. Univariate and multivariate examinations for outliers and missing data (Mahalanobis distance $x^2(8) = 26.125$, $p < .001$; Cooks distance $< 1.0$) were conducted and no outliers were found. However, in the multivariate data screening, the residuals plots from the multiple regression equations depicted a nonnormal relationship in the SCS subdomains BC, D, and C/R. Since the study was exploratory, the variables; age, time and basic concepts variable were of inherent value to the study. Although the age and basic concepts were distributions with nonnormal kurtosis, the scores had unique meaning in their respective measure so transformation was not done. The skewness of time was problematic and transformed logarithmically so that it was useable in the linear equations of this study. Missing data which was due to subjects forgetting or declining to disclose information, were eliminated using listwise deletion.

Item Analysis

Micro-cat Iteman software was used for the item analyses for the total and subdomain SCS scores. Baseline performances were conducted on a set of 15 college students
(low baseline group) who had not taken an introductory statistics class and 24 masters level graduate students (high baseline group) who had completed both undergraduate and graduate statistics. The baseline item analysis results for the low baseline and high baseline groups are found in Table 3 (see Table 3). The group means of the low baseline and high baseline groups were compared and found independent (t = 6.65, p (0.00). The average total SCS p-value of the low baseline group was .29 with a SCS total group mean of 21.67. The high baseline group p-value was .59 with a SCS total group mean of 43.61. The intercorrelational table, found in Table 5, contained low to moderate values (-.02 to .52) for the low baseline group and moderate to high values (.46 to .85) for the high baseline group. The low baseline group had SCS total scores ranging from 13 to 31 and high baseline had SCS total scores ranged from 8 to 60.

The primary group mean was independent from both the low baseline (t = 3.82, p < .00) and the high baseline (t = -8.60, p < .00) groups. The primary group results are also displayed in Table 4 (see Table 4). The SCS scores were normally distributed (skewness = -.12; kurtosis = .38). The SCS total score had an average p-value of .39. According to the individual subtests, the highest to lowest average p-values were: Descriptives (D) = .48; Basis concepts (BC) = .45; Hypothesis testing (HO) = .44; Inferential statistics
### Table 3

**Descriptive Statistics of the Statistical Competency Survey (SCS)—Baseline Study.**

<table>
<thead>
<tr>
<th>Subdomain</th>
<th>Low Baseline group&lt;sup&gt;a&lt;/sup&gt; (n=15)</th>
<th>High Baseline group&lt;sup&gt;b&lt;/sup&gt; (n=24)</th>
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<td>M  s.d.  p</td>
<td>M  s.d.  p</td>
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<tr>
<td>Basic Concepts</td>
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<td>7.83  2.01  .56</td>
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<td>5.47  2.03  .36</td>
<td>8.91  2.03  .59</td>
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<td>3.13  1.31  .20</td>
<td>8.34  2.50  .80</td>
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<td>Hypothesis testing</td>
<td>3.80  2.07  .27</td>
<td>9.70  3.18  .75</td>
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<tr>
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<td>8.83  3.05  .69</td>
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<td>Group Total</td>
<td>21.67  4.50  .29</td>
<td>43.61  11.5  .59</td>
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</table>

**Note.** The Statistical Competency Survey (SCS) is made of 74 items, which is composed of: Basic Concepts (14), Descriptives (15), Correlation/Regression (16), Hypothesis Testing (14) and Inferential (15).

<sup>a</sup>Additional statistics for low baseline group: Basic concepts min/max score = 2-8; Descriptives min/max score = 2-9; Correlations/regression min/max score = 1-5; Hypothesis testing min/max score = 0-8; Inferential min/max score = 0-8; Group min/max .50.  
<sup>b</sup>Additional statistics for high baseline group: Basic concepts min/max score=8-11; Descriptives min/max score = 2-9; Correlations/regression min/max score = 13; Hypothesis testing min/max score =13; Inferential min/max score = 13; Group min/max score = 8-60.
Table 4.
Descriptive Statistics of the Statistical Competency Survey (SCS)—Primary Study.

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Note. The Statistical Competency Survey (SCS), alpha = .70, is made of 74 items, which is composed of: Basic Concepts (14) alpha = .21; Descriptives (15) alpha = .36; Correlation/Regression (16) alpha = .34; Hypothesis Testing (14) alpha = .43; and Inferential (15) alpha = .34. Additional statistics: Basic concepts min/max score = 2-10; Descriptives min/max score = 0-12; Correlations/regression min/max score = 0-10; Hypothesis testing min/max score = 1-11; Inferential min/max score = 0-11; Group min/max score = 9-48.
Correlation/regression (C/R) = .28. The scale alpha coefficients were: Total SCS α = .70; BC α = .21; D α = .36; C/R α = .34; Ho α = .43; I α = .34. Intercorrelational values were low to moderate (.10 to .44) - see Table 5. The mean correct score was 28 out of 74 questions. The lowest individual score was 9 and the highest individual score was 48 (p = .70, standard error of measure = 3.67).

No factor analysis was done for the baseline groups for the sample size, were too small to provide meaningful results. For the primary group, both extraction methods — principle components and factor analysis revealed the same results. So, the scores were forced into a five factor analysis (the most parsimonious solution) using principle components extraction with orthogonal varimax rotation. The loadings of the factor analysis, which was reported with loadings greater than .25, are displayed on Table 6 (see Table 6). Referring to the original five subdomain basis of the SCS and the scree plot in Figure 1 (see Figure 1), five probable factors accounted for 24.7% of the total variance (Factor 1, eigenvalue = 5.79, variance = 6.1%; Factor 2, eigenvalue = 3.51, variance = 5.9%; Factor 3, eigenvalue = 3.10, variance = 4.9%; Factor 4, eigenvalue = 3.06, variance = 3.8%; Factor 5, eigenvalue = 2.94, variance = 4%).
Table 5.

**Intercorrelations for the Baseline and Primary Sample Groups.**

**Intercorrelations of Low Baseline Students**

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**Intercorrelations for High Baseline Students**

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**Intercorrelations of Primary Students**

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Note: The Statistical Competency Survey (SCS) is made of 74 items, which is composed of: Basic Concepts (14), Descriptives (15), Correlation/Regression (16), Hypothesis Testing (14) and Inferential Testing (15). Diagonals represent alpha scale coefficients.

aN=15  bN=23  cN=118.
Table 6

Factor loadings of the Statistical Comprehension Survey (SCS).

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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>72</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>73</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-.34</td>
</tr>
<tr>
<td>74</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Eigenvalue | 5.79 | 3.51 | 3.10 | 3.06 | 2.95 |
| % explained variance | 6.1 | 5.9 | 4.9 | 3.8 | 4.0 |
| Number of scale items | 14 | 15 | 16 | 14 | 15 |
| % correct classification | 35 | 47 | 25 | 7 | 27 |
| Scale Alpha | .21 | .36 | .34 | .43 | .34 |

Note: Underlined loadings are the items that loaded in the hypothesized scale. *BC = Basic Concepts; D = Descriptive Statistics; C/R = Correlation and Regression; H0 = Hypothesis Testing; I = Inferential Statistics. Total scale alpha = .70.
The ATS Scale Reliability

The ATS scale appeared unidimensional (Factor 1 eigenvalue = 8.28, 18.1% of the variance accounted for; Factor 2 eigenvalue 2.02, 16.9% of the variance accounted for; Factor 3 eigenvalue 1.49, 17.4%; Factor 4 eigenvalue 1.29, 15.4% of the variance accounted for). The factor analysis using varimax rotation and principle components extraction derived a solution of four factors accounting for 67.8% of the variance accounted by this set of variables. However, the scree plot in figure 2 (see figure 2) visually depicted one substantial factor that accounted for the set of variables.

The intercorrelations for the ATS are found in Appendix G (see Appendix G). The ATS (scores ranged from one to five per question) had a normal distribution that averaged 2.78 per question (N=106 after listwise deletion) for the subjects in the primary study. The minimum score and maximum ATS scores ranged from 1.47 and 3.64 respectively. The intercorrelations ranged from -.0009 to .70. The scale alpha for the primary sample was .92, which is comparable to the original ATS scale by Wise (1985).

Tests of Hypotheses

The analysis for Hypothesis 1 is found in Table 7 (see Table 7). The harmonic mean for the subscales BC and D ($M = 6.89$, s.d. = 1.99) were greater than the harmonic mean for
Table 7
Planned Harmonic Mean Comparison Between BC and D to C/R, H0 and I.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>s.d.</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic Concepts (BC)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ Descriptives (D)</td>
<td>6.89</td>
<td>1.99</td>
<td>118</td>
</tr>
<tr>
<td>Correlation/regression (C/R)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ Hypothesis testing (H0)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ Inferential (I)</td>
<td>4.95</td>
<td>2.04</td>
<td>118</td>
</tr>
</tbody>
</table>

$t(117) = -7.36^{***}$

Note: *** $p < .00.$

Table 8
The Relationship Between Course Grade and Attitude Toward Statistics.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>s.d.</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Course Grade</td>
<td>3.76</td>
<td>.75</td>
<td>76</td>
</tr>
<tr>
<td>ATS Score</td>
<td>2.79</td>
<td>.30</td>
<td>76</td>
</tr>
</tbody>
</table>

$r = - .30^{***}, t(75) = -10.40$

Note: 1-tail significance
*** $p < .00.$
C/R, H0, and I (M = 4.95, s.d. = 2.04). The means were independent (t = -7.36, p < .00) thus supporting Hypothesis One.

The course grade and attitude toward statistics relationship that was hypothesized in Hypothesis 2 was evaluated through a Pearson r correlation. The relationship between course grade and attitude toward statistics which are found on Table 8 was statistically significant (r = -.30, t(75) = -10.40, p < .00).

The regression formula, which was used to analyze Hypotheses 3 through 7 through the use of beta weights, was adjusted to have a tolerance level of .10 to .15 so that the likelihood of finding predictors from the residual variance was maximized. The forced entry of the set of seven predictors and SCS scores as the criterion, depicted an overall variance of the variable set. Additional regression equations using each of the subsets of SCS gleaned additional information from the set of predictors studied. Since the relationship between the variables in the data set were not perfectly linear, stepwise entry of the predictors (statistically driven entry of variables) provided additional inspection of the stability of the results. The study of predictors and criteria resulted in the beta weights listed in Table 9 for total SCS scores, Table 10 for BC scores, Table 11 for D, Table 12 for C/R, Table 13 for H0.
and Table 14 for I (see Tables 9 through 14).

The forced entry regression equation for the total SCS score in Table 9, revealed that attitude toward statistics was the only significant beta weight out of the set of seven predictors ($\beta = -0.23$, $t = -1.93$, $p = 0.05$, df = 75). The beta weights for the Total SCS equation revealed two statistically significant predictors through stepwise entry: attitude toward statistics ($\beta = -0.24$, $t = -2.14$, $p = 0.04$) and CSUSB Training ($\beta = -0.21$, $t = -1.94$, $p = 0.06$). The betas that failed to be statistically significant were: age, course grade, sex, lab experience, and time.

In Table 10, the forced and stepwise entries of the seven predictors both indicated the same predictor for the BC subscores. Age (forced $\beta = 0.23$, $t = 1.89$, $p = 0.06$, stepwise $\beta = 0.23$, $t = 1.99$, $p = 0.05$) was the only significant beta weight out of the set of seven predictors. The betas that failed to be statistically significant in the different entries were: attitude toward statistics, CSUSB training, course grade, sex, lab, and time.

Likewise, the forced and stepwise entries of the set of seven predictors for the D regression equation in Table 11, revealed that the predictor course grade (forced $\beta = 0.25$, $t = 1.89$, $p = 0.06$; stepwise $\beta = 0.25$, $t = 2.22$, $p = 0.03$) was significant. The remaining beta weights that failed to predict D subdomain were CSUSB training, sex, lab, age,
Table 9:
Regression Equation Results for Total Statistical Competency Survey (SCS).

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE</th>
<th>Beta</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Course Grade</td>
<td>.52</td>
<td>1.17</td>
<td>.06</td>
<td>.45ns</td>
</tr>
<tr>
<td>Gender</td>
<td>-1.91</td>
<td>1.81</td>
<td>-.12</td>
<td>-1.06ns</td>
</tr>
<tr>
<td>Lab experience</td>
<td>-2.63</td>
<td>1.77</td>
<td>-.18</td>
<td>-1.49ns</td>
</tr>
<tr>
<td>CSUSB Training</td>
<td>-1.98</td>
<td>1.69</td>
<td>-.14</td>
<td>1.17ns</td>
</tr>
<tr>
<td>Age</td>
<td>.10</td>
<td>.11</td>
<td>.11</td>
<td>.90ns</td>
</tr>
<tr>
<td>ATS score</td>
<td>-5.41</td>
<td>2.74</td>
<td>-.23</td>
<td>-1.97**</td>
</tr>
<tr>
<td>Time</td>
<td>-4.25</td>
<td>2.57</td>
<td>-.22</td>
<td>-1.65ns</td>
</tr>
<tr>
<td>(Constant)</td>
<td>54.73</td>
<td>11.38</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Forced Entry with Criterion Total SCS

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE</th>
<th>Beta</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATS Score</td>
<td>-5.54</td>
<td>2.58</td>
<td>-.24</td>
<td>-2.14**</td>
</tr>
<tr>
<td>CSUSB trained</td>
<td>-3.00</td>
<td>1.55</td>
<td>-.21</td>
<td>-1.94*</td>
</tr>
<tr>
<td>(Constant)</td>
<td>48.79</td>
<td>7.42</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Stepwise Entry with Criterion Total SCS

Note. Criterion = SCS Total Score. Variables not entered in stepwise: Age, Sex, Time Grade Lab.
*p = .10. **p = .05.
Table 10.
Regression Equation Results for Basic Concepts.

Forced Entry with Basic Concepts (BC)

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE</th>
<th>Beta</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Course Grade</td>
<td>.37</td>
<td>.48</td>
<td>.10</td>
<td>.78ns</td>
</tr>
<tr>
<td>Gender</td>
<td>-.54</td>
<td>.74</td>
<td>-.08</td>
<td>-.73ns</td>
</tr>
<tr>
<td>Lab experience</td>
<td>-1.18</td>
<td>.72</td>
<td>-.20</td>
<td>-1.64ns</td>
</tr>
<tr>
<td>CSUSB Training</td>
<td>.45</td>
<td>.69</td>
<td>.08</td>
<td>.66ns</td>
</tr>
<tr>
<td>Age</td>
<td>.09</td>
<td>.05</td>
<td>.23</td>
<td>1.89*</td>
</tr>
<tr>
<td>ATS score</td>
<td>-1.46</td>
<td>1.12</td>
<td>-.16</td>
<td>-1.30ns</td>
</tr>
<tr>
<td>Time</td>
<td>-.73</td>
<td>1.05</td>
<td>-.10</td>
<td>-.70ns</td>
</tr>
<tr>
<td>(Constant)</td>
<td>9.91</td>
<td>4.65</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Stepwise Entry with Criterion (BC)

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE</th>
<th>Beta</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>.08</td>
<td>.04</td>
<td>.23</td>
<td>1.99*</td>
</tr>
<tr>
<td>(Constant)</td>
<td>4.28</td>
<td>1.21</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. Criterion = BC domain. Variables not entered: ATS Score, Sex, Time, Course Grade, Lab, CSUSB Training.

*p < .10. **p < .05.
Table 11.
Regression Equation Results for Descriptives.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Forced Entry with Descriptives (D) subdomain</th>
<th>Stepwise Entry with Criterion Descriptives</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>SE</td>
</tr>
<tr>
<td>Course Grade</td>
<td>.73</td>
<td>.39</td>
</tr>
<tr>
<td>Gender</td>
<td>-.08</td>
<td>.60</td>
</tr>
<tr>
<td>Lab experience</td>
<td>.59</td>
<td>.59</td>
</tr>
<tr>
<td>CSUSB Training</td>
<td>-.57</td>
<td>.56</td>
</tr>
<tr>
<td>Age</td>
<td>-.03</td>
<td>.04</td>
</tr>
<tr>
<td>ATS score</td>
<td>-.30</td>
<td>.91</td>
</tr>
<tr>
<td>Time</td>
<td>-.22</td>
<td>.86</td>
</tr>
<tr>
<td>(Constant)</td>
<td>7.07</td>
<td>3.78</td>
</tr>
</tbody>
</table>

Note. Criterion = D subdomain. Variables not entered: Age, ATS score, CSUSB Training, Sex, Time, Lab.

*p = .10.

**p = .05.
time, and attitude toward statistics.

Next, in Table 12, the forced and stepwise entries of the C/R regression equation revealed that time was the only significant beta weight out of the set of predictors (forced $\beta = -.30, t = -2.05, p = .04$; stepwise $\beta = -.26, t = -2.36, p = .02$). The betas that failed to be statistically significant in the different entries were: age, attitude toward statistics, course grade, sex, lab, and CSUSB training.

The H0 forced and stepwise regression equations in Table 13, revealed that lab (forced $\beta = -.24, t = -1.94, p = .06$; stepwise $\beta = -.22, t = -2.00, p = .05$) was predictive of hypothesis testing subscores. An additional predictor, course grade (stepwise $\beta = .23, t = 2.08, p = .04$) was added in stepwise entry. The betas that failed statistically after the different entries were: age, sex, CSUSB experience, attitude toward statistics and time.

Finally in Table 14, lab (forced $\beta = -.33, t = -2.88, p \leq .01$, stepwise $\beta = -.31, t = -2.76, p \leq .01$), time ($\beta = -.36, t = -2.83, p \leq .01$), and attitude toward statistics ($\beta = -.23, t = -2.16, p \leq .05$) were supported as predictors of I subdomain using both entry types. The betas that failed to be statistically significant were: age, CSUSB training, course grade, and sex.

Although sex was not a statistically significant .
Table 12.
Regression Equation Results for Correlation/Regression.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Forced Entry with Correlation/regression</th>
<th>Stepwise Entry with Criterion C/R</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>SE</td>
</tr>
<tr>
<td>Course Grade</td>
<td>-.50</td>
<td>.32</td>
</tr>
<tr>
<td>Gender</td>
<td>-.63</td>
<td>.49</td>
</tr>
<tr>
<td>Lab experience</td>
<td>.11</td>
<td>.48</td>
</tr>
<tr>
<td>CSUSB Training</td>
<td>-.18</td>
<td>.46</td>
</tr>
<tr>
<td>Age</td>
<td>.01</td>
<td>.03</td>
</tr>
<tr>
<td>ATS score</td>
<td>-1.17</td>
<td>.75</td>
</tr>
<tr>
<td>Time</td>
<td>-1.44</td>
<td>.70</td>
</tr>
<tr>
<td>(Constant)</td>
<td>11.85</td>
<td>3.11</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. Criterion = C/R subdomain. Variables not entered: Age, ATS score, CSUSB training, Sex, Course Grade, Lab.
*p = .10.
**p = .05.
### Table 13.

**Regression Equation Results for Hypothesis Testing.**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Forced Entry with Hypothesis Testing (H0)</th>
<th>Stepwise Entry with Criterion H0 subdomain</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>SE</td>
</tr>
<tr>
<td>Course Grade</td>
<td>.59</td>
<td>.39</td>
</tr>
<tr>
<td>Gender</td>
<td>-.30</td>
<td>.61</td>
</tr>
<tr>
<td>Lab experience</td>
<td>-1.15</td>
<td>.59</td>
</tr>
<tr>
<td>CSUSB Training</td>
<td>-.55</td>
<td>.57</td>
</tr>
<tr>
<td>Age</td>
<td>.03</td>
<td>.04</td>
</tr>
<tr>
<td>ATS score</td>
<td>-.50</td>
<td>.92</td>
</tr>
<tr>
<td>Time</td>
<td>.12</td>
<td>.87</td>
</tr>
<tr>
<td>(Constant)</td>
<td>8.05</td>
<td>3.83</td>
</tr>
</tbody>
</table>

**Note.** Criterion = C/R subdomain. Variables not entered: Age, ATS score, Sex, Time, CSUSB Training.

*P = .10.

**P = .05.
Table 14.
Regression Equation Results for Inferential.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Forcing Entry with Inferential (I)</th>
<th>Stepwise Entry with Criterion I subdomain</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>SE</td>
</tr>
<tr>
<td>Course Grade</td>
<td>-.36</td>
<td>.34</td>
</tr>
<tr>
<td>Gender</td>
<td>-.13</td>
<td>.52</td>
</tr>
<tr>
<td>Lab experience</td>
<td>-1.47</td>
<td>.51</td>
</tr>
<tr>
<td>CSUSB Training</td>
<td>-.66</td>
<td>.49</td>
</tr>
<tr>
<td>Age</td>
<td>.05</td>
<td>.03</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ATS score</td>
<td>-1.88</td>
<td>.80</td>
</tr>
<tr>
<td>Time</td>
<td>-2.11</td>
<td>.75</td>
</tr>
<tr>
<td>(Constant)</td>
<td>15.41</td>
<td>3.30</td>
</tr>
</tbody>
</table>

Note. Criterion = I subdomain. Variables not entered: Age, Sex, CSUSB Training.

*p ≤ .10 **p ≤ .05 ***p ≤ .01
predictor in the regression equation, the differences between men and women were analyzed by independent \( t \)-tests for Hypotheses 9 and 10. The resulting gender differences are found on Table 15. Men scored significantly higher than women on the C/R subdomain. Yet for this sample, men performed better than women on: SCS total score, BC, D, and C/R. Women actually had higher scores than men in H0 (men = 6.10 and women = 6.22, \( t(116) = -.26; p = .793 \)) and I (men = 4.16 and women = 4.48, \( t(116) = -.74; p = .461 \)). Thus, partial support -- statistically -- was achieved for men performing better than women in statistical competency (e.g., Hypothesis subdomain).
Table 15.
Gender differences on ATS and SCS

<table>
<thead>
<tr>
<th>Variable</th>
<th>M</th>
<th>s.d.</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATS score(^{a})</td>
<td>2.80</td>
<td>.32</td>
<td>(t(104) = .60)</td>
</tr>
<tr>
<td>Men (n=31)</td>
<td>2.84</td>
<td>.32</td>
<td></td>
</tr>
<tr>
<td>Women (n=87)</td>
<td>2.79</td>
<td>.33</td>
<td></td>
</tr>
<tr>
<td>SCS Total(^{b})</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men (n=31)</td>
<td>29.42</td>
<td>6.07</td>
<td>(t(116) = .92)</td>
</tr>
<tr>
<td>Women (n=87)</td>
<td>28.13</td>
<td>6.89</td>
<td></td>
</tr>
<tr>
<td>SCS - Basic Concepts(^{c})</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men (n=31)</td>
<td>7.06</td>
<td>2.71</td>
<td>(t(116) = 1.10)</td>
</tr>
<tr>
<td>Women (n=87)</td>
<td>6.45</td>
<td>2.68</td>
<td></td>
</tr>
<tr>
<td>SCS - Descriptives(^{d})</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men (n=31)</td>
<td>7.45</td>
<td>2.62</td>
<td>(t(116) = .94)</td>
</tr>
<tr>
<td>Women (n=87)</td>
<td>7.02</td>
<td>2.01</td>
<td></td>
</tr>
<tr>
<td>SCS - Correlations/Regressions(^{e})</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men (n=31)</td>
<td>4.97</td>
<td>1.76</td>
<td></td>
</tr>
<tr>
<td>Women (n=87)</td>
<td>4.18</td>
<td>1.98</td>
<td></td>
</tr>
<tr>
<td>SCS - Hypothesis Testing(^{f})</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men (n=31)</td>
<td>6.10</td>
<td>1.87</td>
<td>(t(116) = -.26)</td>
</tr>
<tr>
<td>Women (n=87)</td>
<td>6.22</td>
<td>2.33</td>
<td></td>
</tr>
<tr>
<td>SCS - Inferential(^{g})</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men (n=31)</td>
<td>4.16</td>
<td>1.95</td>
<td>(t(116) = -.74)</td>
</tr>
<tr>
<td>Women (n=87)</td>
<td>4.48</td>
<td>2.12</td>
<td></td>
</tr>
</tbody>
</table>

Note. These are statistics for the primary group.

\(^{a}\) (eta)=.06. \(^{b}\) (eta)=.09. \(^{c}\) (eta)=.10. \(^{d}\) (eta)=.09.

\(^{e}\) (eta)=.18. \(^{f}\) (eta)=.02. \(^{g}\) (eta)=.07.
The researcher examined the plausible influences in the primary student sample from: the content of SCS subsets (Hypothesis 1); the relationship between course grade and student attitude toward statistics (Hypothesis 2); the impact of the student's age (Hypothesis 3); attitude toward statistics (Hypothesis 4); psychology lab experience (Hypothesis 5); taking statistics at CSUSB (Hypothesis 6); time since the last statistics course (Hypothesis 7), course grade in statistics (Hypotheses 8), and sex (Hypotheses 9 and 10) on statistical competence. Gender differences were also examined specifically in statistical proficiency (Hypotheses 9) and attitude toward statistics (Hypothesis 10).

When considering overall statistical competency, the stepwise multiple regression analyses (criterion values: enter tolerance level = .10; delete tolerance level = .15) detected that attitude toward statistics and CSUSB training were successful predictors, thus supporting Hypotheses 4 and 6. The nonsignificant predictors of age and time supported the expected nonrelationship between age with statistical competency and time with statistical competency expected in Hypotheses 3 and 7. However, expected influence of lab experience and course grade failed to support their respective hypotheses (Hypotheses 5 and 8). Sex did not
have a significant beta weight. In the additional comparisons between men and women in the primary student sample, gender differences were not supported for attitudinal differences (Hypothesis 10). However, there was partial support for gender difference in statistical achievement within the C/R subdomain (Hypotheses 9).

In overall statistical comprehension, without a department consensus on the course requirements for CSUSB introductory statistics courses, attitude and CSUSB training were found as predictors in this research. It is plausible that a self efficacy situation was created by administering the ATS scale immediately following the SCS. The ATS results may be limited as a singular event with limited generalization, for the resulting perceptions of the students performance may have influenced the responses of the primary student sample. Measuring attitudinal characteristics void of subjectivity have been difficult to achieve (Crocker & Algina, 1986). So, the best predictor of future behavior has been past behavior (Gatewood & Feild, 1990; Kottke, personal communication May 31, 1995).

The researcher contemplated two approaches to this quagmire. If student attitudes toward statistics is treated as a compound variable affecting the learning capabilities of students, then attitudes are expected to remain successful multi-level predictor in statistical competency.
research. However, if the moderating effect of attitude toward statistics can be controlled (e.g. extracted out statistically or administering the ATS and SCS at different times), then specific behaviors can be addressed to improve statistical comprehension. So, it is suggested that the future researcher should attempt using attitude toward statistics as a covariate in subsequent analyses.

Applying research that acknowledges the anxiety that impedes the learning of statistics has eased the anxiety of students, yet the difficult experience of comprehending statistics by Psychology students has persisted (Ware & Chastain, 1991). So alternative strategies should be explored. The development of potential behavioral strategies are plausible. A possible strategy is to inspect the levels of reasoning and critical thinking that appear in students who do well in statistics and computer science courses (Hudak & Anderson, 1990). The content based questions of the SCS served as an initial prototype to better comprehend the complex nature of statistical knowledge -- which elicited the reasoning abilities of Psychology students.

Limitations of the conceptual format of the test were evident as the researcher investigated the internal consistency of the SCS. The outcome of the extraction methods from the factor analysis (principle components or
principle axis factoring) closely resembled each other -- both comprised of weak loadings after rotations (orthogonal and oblique were identical). So the most parsimonious solution chosen was the use of components instead of factors. Although the loading pattern of the SCS was difficult to interpret, the pattern serendipitously revealed important information on the abilities of the students to answer complex conceptual questions. Numerous scale items in the BC, D, HO, C/R and I factors had loaded across the five factors derived statistically. A pattern appeared in the C/R factor, which loaded largely on the Factor 1 and Factor 2. It seems likely that the factor loading pattern was a reflection of the complexity of SCS questions instead of the content domains that were intended by the researcher. Factorial analyses are useful in the early stages of research by summarizing the relationship between variables and generating hypotheses (Tabachnick & Fidell, 1989). Thus, it was rational to use a factorial analysis -- as a correlational summary of the SCS items.

In retrospect, the researcher found that it was too early to apply additional uses of factor analysis, in which the factor solution provides an explanation to the underlying process of the observed variable (e.g. SCS items). The poor fit of the five statistical subdomains would be expected given the low alpha levels for the
subscales, which is not ideal for stable factor analyses. However, the low alpha levels revealed that the SCS was able to distinguish low and high performance of students. High alpha levels would be suspect of a poorly written test in which low and high student performances were indistinguishable. It is suggested that additional research on the scale reliability of the SCS be expanded by generating additional versions of the SCS in which the test variance is increased among SCS scales. A mix of low, moderate and high levels of item difficulties are sought to maximize test variance (Crocker & Algina, 1986). The use of a large sampling should enhance the correlational relationship between the set of SCS items and potentially improve the 74 item survey.

The investigation of the additional properties of the subdomains of SCS revealed the following predictors within specified areas of statistical knowledge. Age was predictive of the student scores in the B/C domain only — contradicting Hypothesis 3. Course grade was predictive of student scores in the D subdomain — supporting Hypothesis 8. Time was the single statistical predictor for C/R scores — Hypothesis 7 supported. Lab experience and Course grade were predictors of the HO subdomain — supporting of Hypotheses 5 and 8. Attitude toward statistics, Lab experience, and Time were predictors in the I subdomain —
supportive of Hypotheses 4, 5, and 7. The pattern of results from this research should evoke interest from the Psychology Department of CSUSB.

The predictors for the specific subdomains followed a rational pattern — providing evidence to discuss — on a department level — what statistical domain should be taught in the introductory statistics courses and how should it be taught?

Certain domains are stressed in introductory statistics courses — which are often influenced by the instructor’s statistical experience in his or her discipline. Thus Psychology students learn specific statistical domains and may be ignorant of statistical knowledge that would better prepare them for Psychology graduate programs.

The panel of expert PH.D’s who participated in the 1995 Western Psychological Association symposium on statistics held in Los Angeles, would encourage applied teaching methods that address the learning styles of the students. Developing innovative teaching methodology are needed to improve the statistical performance of baccalaureate Psychology students who tend to experience difficulty in learning statistics (Hudak & Anderson, 1990; Jannarone, 1986; Ware & Chasten, 1991). Thus, the predictors found by the present research become increasingly practical. Further investigation of student attributes and the teaching style
of the instructors should review the implications of the following relationships: age and time influencing the cognitive development of baccalaureate Psychology students, the incentive of course grade reinforcing the statistical domains taught in introductory statistics, and the influence of lab experience which incorporates a number of empirical skills that are critical to the field of Psychology. Thus, the SCS was able to measure levels of statistical competency that can potentially enable instructors to identify problem areas of learning and assist their student(s) in comprehending the complex conceptual elements in statistics.

It was suggested by a reviewer to provide a normative comparison between low ability and high ability groups. Thus the baseline study revealed some unique information — regardless of the sample size. It appeared that the average age of the groups were close (low baseline 27.5 years and high baseline 27.3 years). The statistical background was apparent in the performance of the students in the specific subdomains. For the low baseline group, the lowest scores were found in the correlation/regression and hypothesis testing subdomains and the highest scores were in the basic concepts and descriptives subdomains. Whereas, hypothesis testing comprised the highest scores for the high baseline group and basic concepts comprised the lowest scores. The ability to use critical thinking and need for advanced
statistical methodology may have attributed to the nature of score distributions. Thus, the SCS detected different levels of statistical competency.

The hypothesized nature of the content of the SCS was supported in Hypothesis 1. The students were more proficient at Basic Concepts (BC) and Descriptives (D) compared to Correlation and Regression (C/R), Hypothesis testing (H0) and Inferential (I) -- which involved applying more complex concepts. In the item analysis of SCS, the low p-values of the total SCS scores were indicative of the level of difficulty the primary group of students experienced. Specifically by subsets, the low p-values found in the C/R and I domains indicate a clear deficiency among the Psychology students who have already taken statistics. This is a probable reflection of the statistical course material content taught in the classrooms.

What background and experiences cultured the difference in statistical ability of the students of the primary study? A multi-leveled criterion variable for statistical competency was introduced in this study. Furthermore, the SCS provided evidence that the statistical knowledge of the CSUSB Psychology students can be evaluated by a conceptual format. Using the SCS in subsequent research is suggested to enable the researcher to develop the subdomains.
comprising the SCS by increasing the number of subjects to substantiate a factor analysis and foster validity studies.

In the primary student sample, statistical evidence supported the student's attitude toward statistics and taking statistics at CSUSB as the influential predictors that contributed to the overall statistical competency for this sample of CSUSB Psychology students. The precise impact of sex, age, time since last statistics course, statistical grade, and lab experience could not be delineated since the magnitudes of the effect of the forementioned variables were small. Thus replication studies should continue to exam the suspected benefits of single or repeated exposures to statistical principles.

The beta weight for sex failed to be significant in the stepwise multiple regression equation, however partial support for Hypothesis 9 was achieved in statistical ability. The mean comparison between the attitude of men versus women failed to reveal statistical significance. Still, this pattern of gender differences in statistics (and mathematics in general) added to the debate of male superiority to females for statistical performance (Elmore & Vasu 1980, 1986). The only statistical evidence to support gender differences was found within the correlation/regression subdomain. To discern robustness of the superior comprehension of correlation/regression subdomain of men
compared to women, more replication is needed.

The beta weights (positive or negative) in the primary student sample, revealed both unique and general qualities of the Psychology students at CSUSB. Given the direction indicated by the positive beta weight, older students had higher SCS scores than younger students with the exception of the D subscore. Since age of the students had an unexpected significant negative beta weight in the D domain, additional investigation of moderator variables would serve to clarify the role of age. The relationship between time and SCS performance was negative with the exception of the H0 subdomain, which indicated that the SCS students with high SCS scores had probably taken statistics recently. Since CSUSB training was successful in the overall statistical competency, the value of investigating the fit between instructors and their teaching styles to student learning styles -- as suggested in Ware and Chastain (1991) -- is potentially fruitful in incorporating the common experiences of baccalaureate students into the teaching approaches used in the teaching of statistical courses.

It was expected that CSUSB Psychology lab classes should augment the statistical training of students indirectly by requiring literature review, research design, data collection and analysis, and writing research papers (from Psy 311 syllabus at CSUSB). Indications of this --
evident only in the H0 and I subdomains -- were sample specific. More replication is needed to provide understanding in the effectiveness of this predictor.

The substantial effect between positive attitude toward statistics and statistical proficiently (which was measured as SCS and course grade) was replicated supporting the robust factor of attitude toward statistics as a predictor in statistical performance. Positive attitudes which are indicated by low ATS scores, were prevalent among the Psychology students with high SCS scores. Furthermore, there was a significant correlational relationship with a similar inverse relationship between the course grade and a positive attitude toward statistics. Yet, the statistics course grade was only influential to statistical competency in the D subdomain. Since a relationship was found between course grade and attitudes, it would have been desirable to include the complete ATS scale in subsequent administrations of the SCS. These finding should delight Wise (1985) who discussed the inverse relationship between student attitudes toward statistics and the student performance in statistic courses. Again, the positive attitude toward statistics that was revealed by this study, demonstrated that the ATS scale was useful as an outcome measure for assessing important influences on the statistical performance of Psychology students in a baccalaureate program.
Future research needs to expand the demographics to include the student overall grade point average which has been a more successful factor than statistical course grade as suggested by Elmore & Vasu’s research (e.g., Elmore & Vasu, 1991). Potentially, the teaching of statistics to baccalaureate students in the Psychology Department may benefit from the increased understanding of the relationship between the amount of statistical knowledge baccalaureate students learn and the type of statistical knowledge baccalaureate students tend to retain.

Limitations on the Design of the Study

Two limitations of the present study seemed most prominent. First, the exempt research status (i.e., anonymity) enabled the gathering of an adequate sampling of students to consent to the lengthy standardized administration of the SCS, however it limited the results to be exploratory evidence in that no follow up was possible. Larger pools of subjects studied over time are necessary to reliably discern the type and level of statistical competency attainable by CSUSB students. Since statistics has been a requirement for graduation for the baccalaureate candidates in Psychology, the standardized administration of the SCS can be arranged -- even recommended -- while the Psychology students are completing their degree program. In this manner, subjects can be obtained for a longitudinal
study and meta-analyses. Future expansion of the data collection should include: interviews, teaching methodologies and the investigation of learning styles. The resulting information gathered should then be used to refine the SCS instrument which will increase the validity of the instrument as an assessment tool.

Finally, the magnitude and stability of statistical evidence found in this study needs to be bolstered by improving the sample size and cell variance so that more multivariate procedures are made possible. Also, since the pattern of nonnormality was evident in the residuals, the interpretation of the data for the multiple regression equations are limited. Thus, alternate methods of measuring variable relationships which are not perfectly linear need to be considered (e.g. chi-square tests). Given that a cumulative pool of subjects will evolve as subsequent administrations of SCS are studied, advanced multivariate methodologies of factor analysis, path analysis and structural equation modeling would be possible to evaluate the nature of the SCS. Also, the likelihood of committing a Type II error should lessen by using the Cohen Guidelines (Cohen, 1992) to gather a sample size which will allow detection of at least a moderate effect size.
Future Research: Statistical Competency

The current SCS study discerned different abilities among baccalaureate student and graduate students with statistical background and baccalaureate students and college students without statistical knowledge. However, the continued usefulness of the SCS in differentiating the levels of student statistical abilities in this study needs further replication to warrant the utility of the SCS as an empirical tool.

In retrospect, an important factor in statistical performance was not investigated -- the perception of the statistics instructors and their teaching style. Hudak and Anderson have argued that statistical performance can be effected by instructors and their teaching methodology (Hudak & Anderson, 1990). Thus, it is suggested that the student's cognitive maturity and learning style could be studied so that a better fit between statistics instructors and their students can be created.

The credibility of the SCS was augmented by the baseline study conducted on the statistical abilities of the statistically experienced group of masters level graduate students and statistically inexperienced college students. The overall performance of the statistically experienced students on the SCS (mean $p$-value = .59, correlational values for subscores from .44 to .91) was greater than the
performance of the statistically inexperienced students (mean $p$-value=.29, correlational values for subscores from -.12 to .46). Finally, the varying levels of mastery across the different domains of statistical competency were evident by the low scores between the SCS overall and subtest scores in the primary group in which the students had completed the required statistics course as a degree requirement. The generally weak overall statistical performance of the primary group (mean $p$-value = .39, correlational values for subscores from .21 to .70) in this research brings into question, the consequence of lacking a consensus among instructors on what specific knowledge, skills and abilities constitute basic statistical knowledge.

Additional information, reflecting the work of Elmore (Elmore & Vasu, 1979a, 1979b, 1980, Elmore et.al. 1993) should be obtained in the future on the cumulative grade point average, acceptable level of student skills learned through the Psychology Department, past courses and grades in mathematical and computer science courses, and GPA in major. Statistical mastery should be reviewed periodically so that the Psychology Department can incorporate and expand OA at CSUSB with the cooperation and support of the students and faculty members.
**Future Research: Outcomes Assessment (OA)**

Since there is not a consensus of what constitutes the required level of statistical competency among CSUSB professors, the SCS could pose as an initial instrument to assist the Psychology Department in extending OA procedures to the student-level (and be student-centered) as prescribed by the Advisory Committee to the CSU system (Wolfe, 1992).

OA procedures need suitable variables to obtain useful information. Two approaches are suggested as a result of this study. First, the marked difference in aptitude between C/R, D, and H0, I could be studied in more detail to assess the Psychology Department. Finally, OA variables can be extracted from the multiple regression formula in this study which can be applied in an OA of the Psychology Department at the San Bernardino campus within the CSU system. Systematically evaluating the statistical aptitude of students during their baccalaureate study can contribute to the academic accountability that has been sought by the university and the community as in analogous studies by Banta (1988) and Astin (1982, 1988).

The initiation of assessment practices is highly recommended. The following key questions are suggested to generate the critical information for designing an assessment program that achieves educational productivity for the Psychology Department at CSUSB.
1. "Does the statistical background of baccalaureate students foster the ability to retain conceptual statistical knowledge?"

2. "What is the source that is inhibiting the student's ability to use statistics in novel research situations?"

3. "Should a minimal level of statistical competency be set for CSUSB Psychology students and would such a level of statistical mastery improve the quality of research generated by CSUSB students?"

Important outcome variables can be implemented in the OA of the Psychology Department at the San Bernardino campus of the CSU system. Additional information should be obtained in the future on the cumulative grade point average, acceptable levels of student skills learned through the Psychology Department, past courses and grades in mathematical and computer science courses, and GPA in major. Statistical mastery should be reviewed periodically so that the Psychology Department can be alert to the impact OA has on the students and faculty members.

Thus, further OA procedures would provide opportunities to critique teaching standards for statistics and to review the current and potential achievement of student in the Psychology Department at CSUSB. Correlation and regression -- revealed as a weak point in the competency of this
student sample -- needs enrichment or its relevance to the Psychology Department should be determined. It is suggested that the continued use of SCS at CSUSB will be beneficial as a measurement of statistical competency. The empirical basis of the SCS would be strengthened by the development of an item-bank of conceptual statistical questions with established $p$-values. The SCS needs to be revised periodically so that the instrument can be used for validity studies and remain a practical assessment tool.

After evaluating the answers to these questions, assessment should then be patterned according to the suggested Halpern Models of OA -- possibly the program improvement model (Halpern, 1987). OA should enable the major shareholders at CSUSB: the local community, the administration, the Psychology Department and the psychology students, to benefit from assessing weaknesses and rectifying the weaknesses so that the educational productivity at CSUSB will grow. Moreover, expanding system-wide assessment to the departmental level in the Psychology Department is expected to potentially generate an ambiance of quality education that spreads by sharing the vital information of the academic progress of Psychology students and learning what areas of Psychology are beneficial to the success of our students. Though quality education is arguably subjective, focusing assessment
procedures on the learning of CSUSB Psychology students will provide the essential skills designed in the baccalaureate program and supply the evidence of educational productivity of CSUSB.

Thus, Halpern's (1987) arguments would tend to support the merits of promoting a student centered OA procedure locally at CSUSB, in which opportunities to critique teaching standards for statistics and to review the current and potential achievement of students, would benefit the Psychology Department at CSUSB. Correlation and regression -- revealed as a weak point in the competency of this student sample -- needs enrichment or its relevance to the Psychology Department should be determined. It is suggested that the continued use of SCS at CSUSB will be beneficial as a measurement of statistical competency. The empirical basis of the SCS would be strengthened through developing an item-bank of conceptual statistical questions with established p-values. The SCS needs to be revised periodically so that the instrument can be use for validity studies and remain a pragmatic assessment tool.
Test Administration

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For your answer, please turn to page 12. In Part B: On the following pages are 74 conceptual

questions involving statistical concepts. You will not

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Appendix B.

Test Administration for Graduate Students.

Test Administration For Graduate Students

If you are a graduate student Please turn back to page 1.

When answering background questions in Part A:

On question Number 5 List all the statistics courses that you have taken including introduction to statistics, advanced, and applied statistics. Please include:

* The year / semester the courses were taken.
* The full name and city of the college where it was taken.
* Instructor's name
* Your the grade in the class
* Your grade point average (overall and by major if known)
Appendix C.

Consent Form

The test you have been asked to complete contains conceptual questions on statistics. The test is being conducted by Linda Araki to complete a thesis project at California State University San Bernardino, under the supervision of Dr. Ken Shultz, which has been approved by the Institutional Review Board (IRB) of California State University San Bernardino (CSUSB). In this study, the researcher is examining one of the abilities that Psychology students use in applied and/or experimental research.

Your participation is voluntary and though there is no time limit, expect to spend approximately 45 minutes to complete the test. You are not expected to answer all the questions correctly and you can stop at anytime without penalty.

The material and results of this test, (which will be available when the thesis is completed) are strictly confidential and anonymous. The data will be reported in group form only. If there are any questions, please contact the CSUSB Psychology Department, (909) 880-5570 and leave a message for Linda Araki regarding the testing results.

Thank you for your participation.
Appendix D.
Debriefing Form

Debriefing Statement

The test that you have completed was done to examine the level of statistical comprehension among Psychology students. It is unlikely that any psychological or physical harm will result from the completion of this test. Also, the anonymity of your participation and confidentiality of your test scores will remain private according to ethical and professional codes set by the Institutional Review Board which oversees research involving human subjects. The test scores will be available to you after the thesis is completed (the approximate completion date is June 1995). Please contact me, Linda Araki, by leaving a message at the Psychology Department at California State University San Bernardino. A message can be left at (909) 880-5570 and I will respond to your inquires.

To maintain the objectivity of the survey, please do not reveal the nature of the survey to other potential participants.
Appendix E.

Statistical Competency Survey.

ATTENTION: COMPLETE BOTH PART A AND PART B

Part A

DIRECTIONS On the following pages are 74 conceptual questions involving statistical concepts. You will not need a calculator for these questions. There is no time limit. Please read each question carefully, select the best answer, then mark the letter which corresponds to your answer.

Please complete the following background questions:

1. Male ( ) Female ( )

2. Age _______

3. Year in college: Freshman ( ) Sophomore ( ) Junior ( ) Senior ( )
   Graduate ( )

4. Have you taken an introduction to statistics course?
   Yes ( ) No ( )

5. If you have taken an introduction to statistics course, please list the following information for each time you have taken the course (If taken more than once):
   a. Year/semester  b. At which college and the instructor's name  c. Grade you took the class
   (e.g. Winter 1993) (e.g. RCC - Dr Jones) (e.g. B+)

6. If you are enrolled one of the advanced lab classes (Psyc 431, 433, 434, 435, 436, 437 or 438), have you taken introduction to experimental Psychology (Psyc 311)?
   a. Yes ( ) If yes, list your grade __________________________.
      grade semester year
   b. No ( )

7. If you are pursuing a second major or a minor study, list the program(s).
1. When we answer questions about a population with data from a sample, we are using:

A) descriptive statistics.
B) inferential statistics.
C) parametric statistics.
D) non-parametric statistics.

2. A recent report concludes that rats given vitamin supplements have better maze-learning scores than rats on a regular diet. For this study, the independent variable is:

A) the set of rats.
B) maze-learning scores.
C) the type of diet.
D) the difference among the rats.

3. A recent study with college students reports that reaction times in the morning are faster than reaction times in the afternoon. For this report, reaction time is the:

A) independent variable.
B) dependent variable.
C) population parameter.
D) sample statistic.

4. A measurable characteristic of a population is called a(n)

A) parameter.
B) data point.
C) statistic.
D) independent variable.

5. Sampling in which all variable subjects are randomly assigned to the different experimental conditions is called:

A) random sampling.
B) randomized sampling.
C) stratified random sampling.
D) sampling without replacement.

6. The reason that it is incorrect to say that Joan's IQ is twice Jim's IQ is that IQ is not scaled as _____ data.

A) nominal
B) ordinal
C) interval
D) ratio

7. Two sample groups are treated differently and then compared with regard to their performances on a test of short term memory. Statistical hypothesis testing would be used here to

A) eliminate the effects of chance factors from the sample results.
B) determine whether the sample difference is of statistical importance.
C) determine if the population difference is large enough to be of practical importance.
D) decide whether a difference would remain when the effects of
the sampling error are ruled out.

8. The highest point of any frequency curve is most closely associated with the

A) arithmetic mean.
B) harmonic mean.
C) median.
D) mode.

9. Joanne's score of 30 was at the 55th percentile of her class. Which of the following is true?

A) 30% of her class scored above (or equal to) 55.
B) 30% of her class scored below (or equal to) 55.
C) 55% of her class scored above (or equal to) 30.
D) 55% of her class scored below (or equal to) 30.

10. If an IQ distribution is normal and has a mean of 100 and a standard deviation of 15, then 68% of all those taking the test scored between IQS of:

A) 100 and 1005
B) 85 and 100
C) 92.5 and 107.5
D) 85 and 115

11. Elimination of some scores from point near the mean will ___ the standard deviation.

A) not affect
B) increase
C) decrease
D) unpredictably affect

12. The deviations about the mean for four out of a sample of five scores are:-3, +2, +6, -1. The fifth deviation must be

A) -4
B) -2
C) +3
D) +5

13. The t distribution model is designed to correct for error introduced when

A) sampling is not random.
B) sampling is without replacement.
C) the distribution of sample means is skewed.
D) the population standard deviation is estimated.

14. Which measure of central tendency is always at the 50th percentile, no matter what shape the distribution?

A) mean
B) mode
C) median
D) none of the above will always be at the 50th percentile
15. Major-league baseball players are threatening to go on strike, including a minimum salary of $85K. The players' representative is upset about the press coverage of the top few player's salaries while most players earn a fraction of the top salaries. Which of these best represents the players' salaries?

A) mean  
B) median  
C) mode  
D) interquartile range

16. What is the median for the following set of scores?
Scores: 1, 4, 6, 17

A) 4  
B) 5  
C) 6  
D) 7

17. Which of the following will decrease the power of a significance test

A) increasing the sample size  
B) using alpha=.01 versus alpha=.05  
C) using a one-tailed versus two-tailed test  
D) using a dependent versus an independent sample design

18. In order to test the null hypothesis, we must assume

A) the null hypothesis is actually true  
B) we have a normal distribution in our sample.  
C) our underlying population distribution is normal  
D) a level of statistical significance of .05 or .01

19. Measures of central tendency differ in their resistance to the effect of sampling fluctuation. From most resistant to least resistant, the order is:

A) median, mean, mode.  
B) mean, mode, median.  
C) mode, mean, median.  
D) mean, median, mode.

20. Professor Jones performs a t-test of Ho: μ₁-μ₂=0 alpha=.01 and finds a significant difference between the sample means. From this we can infer

A) a large difference between μ₁ and μ₂  
B) a practical and important difference between μ₁ and μ₂  
C) that μ₁ and μ₂ are unequal  
D) all of the above are true

21. In a negatively skewed distribution of exam scores, Tom scored at the mean, Mary scored at the median, and Jane scored at the mode. Who had the highest score?

A) Tom  
B) Mary  
C) Jane
22. The number that tells you how far a raw score deviated from the mean in standard deviation units is a(n):
   A) z-score
   B) average deviation.
   C) deviated raw score.
   D) variance.

23. Almost the entire normal curve is bounded by ____ standard deviation units.
   A) 2
   B) 3
   C) 4
   D) 5

24. Of two golfers, each of whom drives the ball the same average distance, the one with the smaller standard deviation would be:
   A) the more consistent.
   B) the less consistent.
   C) the one more apt on a given shot, to drive the ball further.
   D) none of these; both drive the ball the same average distance.

25. A class of nine students took an achievement test. The distribution of their marks turned out to have a mean of 6 and a standard deviation of 0. What were the nine test scores obtained.
   A) All scores are 6.
   B) All scores are close to the mean.
   C) The scores are widely spread.
   D) Impossible to say without further information.

26. A one-tailed hypothesis test should be used when
   A) the outcome of the test is in a particular direction.
   B) there is reason to believe the outcome will point in a particular direction.
   C) the experimenter so chooses; it is simply a matter of personal preference.
   D) the experimenter has no concern if a difference is found in a direction opposite to the stated in the alternative hypothesis.

27. According to the information contained in the sampling distribution, we reject the null hypothesis if the probability of obtaining such a sample is
   A) known
   B) estimated
   C) low
   D) high

28. I developed a cure for the AIDS virus. Unfortunately, I ran the test of the vaccine in a small sample, low power study and failed
to reject the null hypothesis. What type of error did I commit?

A) Type I (alpha)
B) Type II (beta)
C) Type III (omega)
D) No error, the null should not have been rejected

29. A score of 85 is earned on a test in which the mean is 100 and the standard deviation is 15. An equivalent score on a scale with a mean of 50 and a standard deviation of 10 is:

A) 35
B) 40
C) 45
D) 50

30. The correlation coefficient is obtained between academic aptitude test score and academic achievement (a) among students in general, and (b) among honor students. Other things being equal, we expect the

A) first to be higher
B) the second to be higher
C) first to be positive and the second negative
D) two coefficients to be about the same

31. When a curved line is the line of best fit to the points of a bivariate frequency distribution, Pearson r will describe:

A) how well the points hug the curved line..
B) how well the points hug the best fitting straight line.
C) how well the points hug a line intermediate between the curved line and the straight line.
D) none of these.

32. Which value of r permits the greatest accuracy of prediction?

A) +.78
B) +.27
C) -.37
D) -.81

33. A researcher has observed that writers who smoke cigarettes are more productive than writers who do not smoke cigarettes and that in a large sample of writers, the correlation between the number of cigarette smoked and the number of pages written was .27. The researcher can conclude that:

A) smoking cigarettes causes productivity.
B) smoking cigarettes may be associated with greater productivity.
C) smoking cigarettes may inhibit productivity.
D) smoking is a "good release" for writers.

34. To learn how well we can predict Y form knowledge of X, we calculate r and find it to be r = -1.16. From this, we know that:

A) high values of X are predictive of low values of Y.
B) the score in Y are generally low.
C) the mean of X is higher than the mean of Y.
D) we have made a mistake in calculation.

35. Which value of \( r \) indicated the strongest degree of relationship?

A) +.08
B) -.12
C) -.85
D) -.98

36. Which of the following would be most likely to show a negative correlation?

A) reaction time and skill as a driver.
B) height and shoe size.
C) hours studied and exam grade.
D) weight of automobile and gas used per mile.

37. Among a group of children, the correlation between test score in a science course and test score in an English course is +.45. The instructor finds out that each science test score is 5 points too high, so each score is corrected and the \( r \) recomputed. We expect that its value will be:

A) greater than +.45.
B) less than +.45.
C) changed in an unpredictable way.
D) unchanged.

38. According to their grades on the first exam, an instructor identifies the 10 best students among his class of 100. Their average grade is A-. After the next exam he reviews their performances. He will probably find that their average grade on the second exam will be

A) higher.
B) about the same.
C) lower, but above average.
D) about average.

39. The standard error of prediction measures variability of:

A) predicted scores about the mean.
B) predicted scores about the regression line.
C) obtained scores about the mean.
D) obtained scores about the regression line.

40. A local nightclub has a $5 entrance fee and charges $2 per drink. Which of the follow equations describes the relation between the total cost (Y) and the number of drinks purchased (X) in a single night out?

A) \( Y = 5X + 2 \).
B) \( X = 5Y + 2 \).
C) \( Y = 2X + 5 \).
D) \( X = 2Y + 5 \).

41. The primary reason we use a scatter plot in linear regression is:
A) to determine if the relationship is linear or curvilinear.
B) to determine the direction of the relationship.
C) to compute the magnitude of the relationship.
D) to determine the slope of the least squared regression line.

42. In one study, a correlation of -0.49 is found between the number of hours of TV watched per week and high school GPA. According to this study ___ of the GPA variance is associated with TV watching.
   A) 14%
   B) 24%
   C) 49%
   D) 70%

43. With increases in sample size, the standard error of the mean:
   A) increases.
   B) stays the same.
   C) decreases.
   D) varies randomly.

44. We conduct a two-tailed test at the .05 level of significance with data that afford 4 degrees of freedom. When we look up the critical value of \( z \), we will expect it to be ____ the corresponding critical value of \( z \) from the normal curve table.
   A) substantially larger than
   B) a little larger than
   C) a little smaller than
   D) substantially smaller

45. The region of rejection typically appears where in the sampling distribution?
   A) above the mean
   B) below the mean
   C) in the center
   D) at the extremes

46. The first step in hypothesis testing is to:
   A) locate the values associated with the critical region.
   B) collect the sample data.
   C) make statistical decision about the null hypothesis.
   D) state the hypotheses.

47. The null hypothesis is a statement that is:
   A) believed to be true until proven false.
   B) considered likely to be true.
   C) believed to be false until proven true.
   D) set up for the purpose of evaluating its truth or falseness.

48. If the same experimental subjects are given each of two treatments, the experiment has a(n):
   A) repeated measures design.
   B) matched pairs design.
   C) independent subjects design.
49. The test between dependent means requires that one must take special account of the:
   A) correlation between the two sets of measures.
   B) standard deviation of the two variables.
   C) case of equal sample size.
   D) assumption of normality.

50. One-way ANOVA can be considered an extension of:
   A) the t test for independent groups.
   B) test for homogeneity of variance.
   C) simple randomized design.
   D) simple ANOVA.

51. Variability between groups is assumed to result from individual difference, experimental error, and:
   A) total variability.
   B) within-group variability.
   C) a treatment effect.
   D) degrees of freedom.

52. The F-ratio is the ratio of:
   A) between-group variability to total variability.
   B) between-group variability to within-group variability.
   C) total variability to within-group variability.
   D) within-group variability to between-group variability.

53. The F distribution is like the t distribution in that:
   A) its mean is zero.
   B) it is symmetrical.
   C) it is actually a family of distributions.
   D) both positive and negative values are possible.

54. For an experiment comparing more than two treatment conditions you should use ANOVA rather than separate t test because:
   A) you are less likely to make a mistake in the computations of ANOVA.
   B) a test based on variances is more sensitive than a test based on means.
   C) ANOVA has less risk of Type I error.
   D) ANOVA has less risk of Type II error.

55. The purpose of a post hoc test is to determine:
   A) which treatments are different.
   B) how much difference there is between treatments.
   C) whether or not Type I error was made in the ANOVA.
   D) whether or not complete ANOVA is justified.

56. When sample size is very large, we may find that:
   A) r is shown to be significantly different from zero when the
true value of rho is not importantly different from zero.
B) the standard error of the sampling distribution cannot be determined.
C) large values of r may suggest that we should retain the hypothesis that rho = 0 when it is false.
D) the sampling distribution is not normal.

57. In comparison to parametric statistics, nonparametric tests are typically:
A) more powerful.
B) less powerful.
C) less accurate.
D) more efficient.

58. A fatigued cafeteria manager wants to see how much relationship there is between the order of arrival of his customers and their order of departure (i.e., are the ones that come for lunch at the earliest possible time also the first ones to leave?) What measure of association should he use?
A) Pearson r
B) Spearman r
C) Cramer's phi
D) Chi-square

59. In concept, the regression line is most closely related to which of the following statistical notions?
A) median
B) mean
C) variance
D) standard deviation

60. Fifty students take a 100-item true-false test. Every student attempts every item. For each student, let X be the number of questions answered correctly and Y be the number not answered correctly. We would expect r_{xy} to be
A) zero
B) +1.00
C) -1.00
D) not enough information provided

61. In general, "degrees of freedom" is most closely related to the
A) value of the sample mean
B) value of the sample standard deviation
C) sample size obtained in our study
D) level of significance use to test the null hypothesis

62. Sums of squared deviations and degrees of freedom are used to arrive at
A) the t-ratio
B) variance estimates
C) population standard deviations
D) sampling distributions of the mean
63. I want to know if IQ and GPA are significantly related. I have continuous data for both of these variables for 493 subjects. What type of statistic is most appropriate to the resolution of my question?

A) t  
B) F  
C) r  
D) Wilcoxon T

64. Your weight best exemplifies which of the following type of measurement scale:

A) nominal  
B) ordinal  
C) interval  
D) ratio

65. I have demographic data describing the political affiliation and gender of an adequate sample of subjects. I want to know if the two are related. What is the most appropriate test?

A) t  
B) Mann-Whitney U  
C) Chi-square  
D) Binomial test of probability

66. Which of the following is not a variable?

A) weight of any U.S. citizen  
B) IQ of any Texan  
C) eye color of any student  
D) age of Mickey Mantle on June 4, 1953

67. I am letting a computer do my calculations for the first time. It computes an F-test, reports the F value, and give me an p-value of .0332. Without looking up the F value in an F table, what can I do now?

A) nothing, you still need to find a critical value for F.  
B) you will fail to reject the null hypothesis.  
C) you will reject the null hypothesis given the standard alpha error tolerance of .05.  
D) you will report a Type I error.

68. A judge wants to decide which of two parole programs has a greater success rate. She does not know in advance which one is more effective. She should

A) conduct two separate one-tailed tests, one in each direction.  
B) require a two-tailed test.  
C) allow the alpha level to determine the choice of test.  
D) make sure that alpha + beta = 1.

69. If the sample size is large, the distribution of sample means from a skewed population is

A) skewed.
B) random.
C) bimodal.
D) approximately normal.

70. We wish to estimate how John will perform academically in college from his score on an academic aptitude test. This is most directly a problem in
A) inference.
B) sampling.
C) prediction.
D) description.

71. When the average scores for two groups are found to be "statistically significant," it means that the results
A) are important
B) are of practical use
C) had a low probability of occurring by chance
D) all of the above

72. A basic aim of statistical inference is to form a conclusion about a
A) sample.
B) random sample.
C) population.
D) random population.

73. In a two group experiment, random assignment
A) insures lack of bias in the experiment
B) insures lack of bias in the long run
C) insures equality of the two groups
D) is important solely for statistical reasons

74. Which of the following is correct with regard to the use of matched groups as a method of experimental control?
A) we can assure control over any irrelevant variable that might effect the results
B) we may "match out" too much or too little
C) matching should be used instead of random assignment where possible in order to assure more precise control
D) through matching, we can usually compensate for any inadequacies in our research design

THIS IS THE END OF PART A, PLEASE TURN TO PART B ON PAGE 12.
Part B

DIRECTIONS For each of the following statements mark the rating category that most indicates how you currently feel about the statement. Please respond to all of the items.

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<th>Strongly agree</th>
<th>Strongly agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly disagree</th>
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</table>

1. I feel that statistics will be useful to me in my profession.

2. A good researcher must have training in statistics.

3. Most people would benefit from taking a statistics course.

4. I have difficulty seeing how statistics relates to my field of study.

5. Statistics will be useful to me in comparing the relative merits of different objects, methods, programs etc.

6. Statistics is not really very useful because it tells us what we already know anyway.

7. Statistical training is relevant to my performance in my field of study.

8. Statistics is a worthwhile part of my professional training.

9. Statistics is too math-oriented to be of much use to me in the future.

10. Statistical analysis is best left to "experts" and should not be a part of a lay professional's job.

11. Statistics is an inseparable aspect of scientific research.
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<td>12. I am excited at the prospect of actually using statistics in my job.</td>
<td>Strongly agree</td>
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<td>13. Studying statistics is a waste of time.</td>
<td>Strongly agree</td>
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<td>14. My statistical training will help me better understand the research being done in my field of study.</td>
<td>Strongly agree</td>
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<td>15. One becomes a more effective &quot;consumer&quot; of research findings if one has some training in statistics.</td>
<td>Strongly agree</td>
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<td>16. Training in statistics makes for a more well-rounded professional experience</td>
<td>Strongly agree</td>
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<td>17. Statistical thinking can play a useful role in everyday life.</td>
<td>Strongly agree</td>
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<td>19. Statistical training is not really useful for most professionals.</td>
<td>Strongly agree</td>
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<td>20. Statistical thinking will one day be as necessary for effective citizenship as the ability to read and write.</td>
<td>Strongly agree</td>
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Source: Reproduced from the **Attitude Toward Statistics** scale by Steven Wise at the University of Nebraska-Lincoln.
Appendix F.

The operationalization of the sample domain:

Basic Statistical Concepts

In this content domain, the individual's knowledge of important statistical terms are recalled and applied to common statistical application. The comprehension of the statistical terms, the interrelatedness of terms, the appropriate assumptions, and the associated consequences are expected to be important factors impacting the individual's proficiency in statistics.

For example:

When we answer questions about a population with data from a sample, we are using:

A) descriptive statistics.
B) inferential statistics.
C) parametric statistics.
D) non-parametric statistics.

Descriptive statistics

In this content domain, the individuals must use their statistical knowledge to recognize and identify the use of descriptive statistics. Descriptive statistics have limited use, supplying a superficial level of description of the data set.

For example:
A skewed curve with its tail to the right is called:

A) negatively skewed.
B) positively skewed.
C) symmetrically skewed.
D) normally skewed.

Correlation/Regression
In this content domain, understanding the relationship between correlations and regression is the latent variable which underlies the individual responses to questions.

For example:

The correlation coefficient is obtained between an academic aptitude test score and academic achievement (1) among students in general, and (2) among honor students. All things being equal, we expect:

A) the two coefficients to be about the same.
B) the first to be higher.
C) the second to be higher.
C) one to be negative, the other positive.

Hypothesis Testing
This content domain taps the individuals's knowledge of the general theory of hypothesis testing using critical thinking and logical abilities in addition to the basic statistical concepts. The skills involved include: testing assumptions and using statistical analyses to prove and disprove hypotheses. Understanding the relationship between
magnitude, stability, and how representative is the data set of the population being tested, so that conclusions can be drawn.

For example:

I developed an cure for the AIDS virus. Unfortunately, I ran the test of the vaccine in a small sample, low power study and failed to reject the null hypothesis. What type of error did I commit?

A) Type I (alpha)
B) Type II (beta)
C) Type III (omega)
D) No error, the null should not have been rejected

Inferential statistics

The content domain taps the individuals ability of inductive reasoning building on the basic statistical knowledge base (mean, standard deviation, variance, statistical significance), in order to apply statistical techniques, probability tables to make inferences regarding the data.

For example: t-test, F-test, ANOVA, z-score

One-way ANOVA can be considered an extension of:

A) the t test for independent groups.
B) test for homogeneity of variance.
C) simple randomized design.
D) simple ANOVA.
Appendix G

Correlations of ATS Scores

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Correlations of ATS Scores continued.

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Appendix H.
Correlations of Stepwise Multiple Regression Equations.

### Correlational Table - Total SCS

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### Correlational Table - Correlation/Regression

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1. Correlation 1.00  
   Regression

2. Course  
   Grade

3. Sex

4. Lab  
   Experience

5. CSU  
   Training

6. Age

7. Time  
   Time

8. ATS  
   ATS

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### Correlational Table - Hypothesis testing

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1. Hypothesis 1.00  
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108
## Correlational Table - Inferential

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### Note
- "**" indicates significance at the .01 level.
- "*" indicates significance at the .05 level.
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Listwise deletion. 1-tail significance. N=76.
* p<.05  ** p<.01
Figure 1.
Scree Plot of SCS.
Figure 2.
Scree Plot of ATS.
REFERENCES


Quesnell, J.J. (1995, April) To be or not to be significant in the information-consuming lives of our introductory students. Abstract presented at WPA convention in the symposium Whither statistics: What should we teach and how?


