ASSOCIATION OF COURSE PERFORMANCE WITH STUDENT BELIEFS: AN ANALYSIS BY GENDER AND INSTRUCTIONAL SOFTWARE ENVIRONMENT

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Claims and counter claims characterize the debate about the impact on learning related to educational technologies. We hypothesize that some of the impact may reflect the influence of the technology on student subject-related beliefs and that those beliefs may differ by gender. We desired to assess how course performance may be associated with student beliefs, and how the association may differ depending on instructional software environment and gender.

1 INTRODUCTION

An experiment in an algebra-based introductory statistical methods course presented an opportunity to assess the influence of instructional software environment on the association between student beliefs and subsequent course performance. The influence of student gender on the connections between belief, performance and software environment is also of interest. The motivation for this investigation is stated by Gal, Ginsburg, and Schau 1997, "… in order to make the learning of statistics less frustrating, less fearful, and more effective … further attention by statistics educators should be focused on the attitudes and beliefs students bring into statistics education experiences …". In this study, beliefs about quantitative confidence, general academic confidence, quantitative background, and the importance of quantitative skill to future success were measured with a pre-course self-assessment. Here beliefs are defined as individually held ideas about statistics, about oneself as a learner of statistics, and about the social context of learning statistics (Gal et al. 1997). Among the questions of interest are: 1) is there an association between pre-course beliefs and course performance? 2) does evidence of association remain stable throughout the course? 3) does the association differ for females and males? 4) does the association depend on the instructional software package used? The answers to these questions have implications for designing intervention strategies for improving teaching and learning of statistics.

Research investigating student beliefs about science, math, and statistics has been conducted by a number of authors (Gal and Ginsburg 1994; Shamos 1995; Seymore and Hewitt 1997; Wisenbaker and Scott 1998). Much of this work suggests that capable students are overtly discouraged from their interest or potential interests in science and math. Negative beliefs can impede learning, hinder development of useful intuitions, and reduce application outside the classroom (Gal and Ginsburg, 1994). Most theories on academic motivation involve the premise that lack of self-confidence leads to a reluctance to try (Cross and Steadman, 1996). Rouse (1995) notes many negative beliefs among students about math, including a lack confidence in their ability to do math. Although distinctions can be made about the influence of negative beliefs in science education, math education and statistics education, Gal et al. (1997) note that beliefs, achievement, and persistence influence each other in statistics education in ways similar to mathematics and other areas. There are differences as well. Huang and Brainard (2001) found female students' self-determinants of math self-confidence to be different from factors that determine science self-confidence. Sax (1994) notes that traditional predictions of math confidence operate differently for males and females at college entrance.

In addition to potential differences in the association between beliefs and course performance due to gender differences or science, math, or statistics focus, there may be differences due to instructional materials employed. Shaughnessy (1992) suggested using computer software to change student beliefs. Moore (1997) notes that video may be used to change the beliefs of viewers at a subconscious level so instructional software that includes carefully constructed video components may be more effective at changing beliefs than software without video clips. Adaptive technologies are frequently cited as an important way to address this challenge and others associated with improving instruction (NSF, 1996; Derry, 1992; McCalla, 1992). In addition to presentation of learning content in these technologies, much attention has been placed on the importance of the design, particularly focused on the user interface and ease of use (Nielsen 2000; Reigeluth 1999; Schneiderman 1998; Ware 2000).

2 MATERIALS AND METHODS

2.1 The experiment

The experiment was implemented in an introductory algebra-based statistical methods course. This course satisfied a general education requirement for mathematics proficiency at Washington State University and satisfied a requirement of many departments. The students came from broad backgrounds of previous mathematical and statistical knowledge and current academic interests. Two-thirds of the 172 students were female and 95 percent were between the ages of 18 and 24.

The course consisted of three hours of lecture instruction per week and a two-hour weekly laboratory session. There were two lecture sections of the course. One section was divided into three laboratory sections and the other larger lecture class was divided into six laboratory sections. Each laboratory section was assigned one of two instructional software packages to be used in the laboratory for the entire semester. To reduce instructor influence on overall differences among the beliefs and performances of students, a single instructor volunteered to teach both lecture sections of the course. The same textbook was used for both lecture sections. All three teaching assistants were assigned the same number of laboratory sections from each instructional software package. All students in a laboratory section used the same instructional package. For administrative convenience the three laboratory sections associated with the smaller lecture class used one package and the six sections associated with the larger lecture class used the other. Because the treatments were applied to laboratory sections, rather than to individual students, the laboratory section was considered the experimental unit for comparing instructional packages.

Two instructional software packages ActivStats and CyberStats, were the treatments used in this study. These packages were chosen because we agree with Lee (1998) that introductory statistics should be taught using real world data, student activities, and computer technology. The decision not to use a formal control group with no instructional software treatment is consistent with an approach that assumes differential impacts of different instructional methods. Product information for ActivStats claims that students will experience real world examples, learn key statistics concepts through specially designed simulations, and practice with interactive experiments. The CyberStats web page lists the following principles: learning by activity and discovery, real data in real-world settings, and a stress on conceptual understanding. Each package contains its own version of a computational statistics program that both interfaces with the topical lessons, and is available for use independently of the instructional activities. CyberStats is a world-wide-web based program. Students pay a fee for a password that gives them access to the material for the duration of the academic term. ActivStats is purchased on a CD-Rom. The cost for each package was comparable.

Despite similarities in the two software packages they reflect two distinct instructional strategies. ActivStats embodies design principles that reflect assumptions that learners benefit from a greater contextualization of the problems, a contextualization that situates the learning of statistics in world problems, and it places a conspicuous emphasis on organizing the learning of statistics around the primacy of broad concepts. The interface, consistent with those assumptions, provides links to videos that explore the context in which the statistical analysis will be provided, and the statistics are organized around concepts like "understanding data, understanding relationships, and generating data." For instance, instead of introducing the concept of regression, the organization subordinates the statistical methods to the umbrella concepts of relationships between things, and it presents videos. For instance a short video on the plight of the manatee is used to introduce the relationship of the animal to human incursions in the Everglades. In this context, regression is introduced as a tool to examine the relationships between human incursion and a declining animal population.

The CyberStats package reflects principles that hold the importance of the mathematical underpinnings of statistics. The different statistical methods shape the organization of the material, moving from the more basic principles to the more complex. The interface is designed to sequentially present the information about the statistical concept, including definition of terms. It then presents opportunities to practice the procedure. In addition, the package integrates the mathematical and statistical concepts with interactive models that demonstrate the graphical representation of the concept.

3 Survey instrument

At the first laboratory session, the students completed a questionnaire with 39 questions. The survey contained these general constructs:

- general confidence;
- math and statistics confidence, referred to as math concern to distinguish it from general confidence;
- previous performance or ability (the blurring of the construct reflects shortcomings with previous measures of performance or ability such as the Scholastic Aptitude Test (SAT);
- gender, often recognized as a predictor for math and statistical performance.

The survey was modeled, with permission, after Angelo's and Cross' (1993) "Teaching Goals Inventory." Angelo and Cross drew in particular on work by Kulik (1976) and Bowens' (1977) efforts to explore students learning "dispositions" to shape their work on students' reactions to instructions, aspects of the TGI which were particularly useful in our adaptation of the instrument. In addition to extracting and adapting questions from Angelo's and Cross' instrument, we focused questions specifically on issues of general confidence and beliefs toward learning and toward confidence in math and statistics in particular, in order to explore issues that research suggests is promising but in which results are mixed (Leder, G. C., Pehkonen, E., and Törner, G. 2002). The first page of the questionnaire is presented in Appendix A. A similar questionnaire was given during the final laboratory session. An analysis of the difference between post and pre-class responses due to educational software treatment may be found in Alldredge and Som (2002).

Assessment of student learning included two mid-semester exams and a final exam based on topics covered in both the lecture and laboratory portions of the class. An additional comparison used total course points including all exams, scores compiled from in-class and laboratory activities, lecture and laboratory homework assignments, and two class projects. The projects, although containing statistical analysis, were largely written works and graded for pertinent statistical content and quality of writing. Students' pre-course quantitative and verbal skills were assessed through SAT verbal score, SAT math score, and SAT total score.

4 Statistical methods

A mixed model analysis of variance was used to explore the relationship between course performance and student pre-course beliefs. In order to reduce the dimensionality of the questionnaire and identify the underlying patterns of variation in the data set, a multivariate principal component analysis (PCA) was conducted for females and males combined, as well as separately. Analysis of variance and covariance were used to test for association between factor scores identified by the PCA and course performance, while considering the effect of instructional package used and gender. We also tested the association between pre-course questionnaire item responses and overall course grade with the Jonckheere-Terpstra (JT) statistic for all laboratory sections combined and for the ActivStats and CyberStats laboratory sections separately. This statistic allowed testing a directional hypothesis between each item on the pre-course questionnaire and the final course grade. All analyses were completed for females and males combined as well as for females and males separately to determine if there were gender differences in the association.

5 RESULTS

Principal component analyses provided varimax rotated factor patterns allowing labeling of two new variables that were linear combinations of the original response variables for females alone, males alone and females and males combined. One of the linear combinations identified for each of these situations was related to feelings of general confidence by students in their ability to do well in school (General Confidence). A second factor identified for each situation was composed of items related to the student's self-reported concern about their ability to do math (Math Concern).

Associations between General Confidence factor scores and exam performance were positive for both males and females throughout the course but not significantly so after the first exam for females and after the second exam for males. That is, association between General Confidence and course performance became weaker over time for both males and females. There was no association between final exam score and General Confidence factor. However, there were differences in the association between course performance and General Confidence when instructional package was considered. For females the Cyberstats group showed a more positive association between overall course grade and General Confidence than the female ActivStats group. In contrast, for males the questionnaire items related to General Confidence have a more positive association with overall grade for the ActivStats group than for CyberStats.

Associations between the Math Concern factor and exam performance were consistently negative throughout the course. That is, students who expressed more concern with their ability to do mathematics tended to have lower scores on all exams. This negative association was stronger for females than for males. In fact, even after adjusting female course performance for their SAT math score, there was a significant negative association between self-assessment of concern with doing math and all exam scores. Females scored significantly higher than males on all exams except the first but had a significantly lower score on questionnaire item 3 (I have confidence in my ability to do math).

The JT test revealed associations between several items on the pre-course questionnaire and final course grade. Some associations were consistent for both males and females for both instructional packages, while others indicated differences in significance depending on gender and instructional package. Items 1, 2, and 17 that relate to General Confidence all had significant positive associations with course grade for males in the ActivStats group but not for males in the CyberStats group. For females items 1 and 17 were significantly positively associated with final course grade for the CyberStats treatment group but not for the ActivStats group where items 2 and 17 had significant negative associations with final course grade for females. Items 4, 6, and 19 that relate to Math Concern all had significant negative associations with course grade for females in the CyberStats group but not for the ActivStats group. For males item 4 had a significant positive association with final grade for the CyberStats group and a significant negative association for the ActivStats group. Like the females, males showed a negative association between item 6 and final grade for the CyberStats group.

6 DISCUSSION

The findings reported in the previous section suggest that there are complex gender differences in the associations between pre-course beliefs and course performance, but that association is not necessarily stable throughout the course. Further, it appears that the software packages may influence the associations between beliefs and learning outcomes differently. Specifically, CyberStats appears to allow a stronger relationship between General Confidence and course performance than ActivStats for females while the opposite is true for males. ActivStats seems more effective in ameliorating the effect of Math Concern on course performance compared to CyberStats for females but not for males. It may be that ActivStats, with its greater focus on context, may better amend the negative attitudes females have towards mathematics than CyberStats. The implications of the complex relationship between strategies that encourage confidence and those that improve performance, and the findings suggest that those strategies and outcomes are not at all the same, especially for women. This raises serious issues about the efficacy of our measures, tests, and instructional strategies that certainly merit additional research. The finding that the same association between Math Concern and course performance is not affected by either software package for males further exacerbates the complexity. Again, the complexity is underscored by the finding that females scored significantly higher than males on all exams except the first, and achieved more total course points. Despite these generalizations, it appears that there are complex differences between males and females in the influence of software packages on the association between their beliefs and course performance. Further, it should be noted again that the combined scores for male and female students in laboratories that used ActivStats had significantly higher mean scores for all exams as well as total course points compared to students in the CyberStats laboratories (Alldredge and Som 2002). The technology that was designed to expand the context of statistics and that emphasized the methods of statistics through use of video components as ways to examine the context was more effective in terms of course performance for many students than was the technology that placed a more immediate focus on statistical methods, though the latter used examples as well. The distinction might be simplified. The more effective approach focused on statistics as a set of tools useful for examining the world; the less effective approach focused on statistics as an end, as content to be learned.

What emerges is that persistent skepticism about the efficacy of technology as a way to improve learning is misdirected, and the findings in this study contribute to the growing body of research that argues that point. Researchers need to move beyond the simple question, "Does IT work?" and examine instead the complex nuances of instructional design and the underlying strategies associated with that design, with or without technology. The differential findings in this study illuminate this point. Future research on intervention strategies to improve learning will benefit from attention to the complexity of the association between student beliefs and student learning.

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APPENDIX A
MATHEMATICS & STATISTICS 212

FALL 2000

Your feedback preceding this course will provide important and useful information for the course developers, the department, and the university. Please read the instructions carefully before giving your answers. Thank you for participating in this project.

Student ID #	**Gender: M F**
Your TA's name:	**Your Major:**
Year in School:	**Minor (if applicable):**

Part I: Background

Indicate how strongly you **agree** or **disagree** with each of the following statements:

(mark the appropriate circle, select only one response per question)

		Strongly agree	agree	somewhat	disagree	strongly disagree
1.	I have confidence in my ability to do well on exams.	❍	❍	❍	❍	❍
2.	I have confidence in my ability to write well.	❍	❍	❍	❍	❍
3.	I have confidence in my ability to do math.	❍	❍	❍	❍	❍
4.	Math formulas confuse me.	❍	❍	❍	❍	❍
5.	I have a good background in statistics.	❍	❍	❍	❍	❍
6.	My previous instruction in math was poor.	❍	❍	❍	❍	❍
7.	I am usually systematic in my approach to problem solving.	❍	❍	❍	❍	❍
8.	I am usually well prepared for math exams.	❍	❍	❍	❍	❍
9.	Math skills are essential to my academic success.	❍	❍	❍	❍	❍
10.	I am generally good at visualizing concepts.	❍	❍	❍	❍	❍
11.	I usually study math with friends.	❍	❍	❍	❍	❍
12.	Math requires extensive mental discipline.	❍	❍	❍	❍	❍
13.	My previous instructors are responsible for my attitude toward statistics.	❍	❍	❍	❍	❍
14.	My family are pretty good in math.	❍	❍	❍	❍	❍
15.	Stat skills are essential to my future career.	❍	❍	❍	❍	❍
16.	People who are exceptionally good in math are often perceived as odd.	❍	❍	❍	❍	❍

Indicate how strongly you **agree** or **disagree** with each of the following statements:						
(mark the appropriate circle, select only one response per question)						
17.	When I apply myself, I do well in school.	❍	❍	❍	❍	❍
18.	In the past, I have generally gotten help in math from family or friends.	❍	❍	❍	❍	❍
19.	When I struggle with math I feel unintelligent.	❍	❍	❍	❍	❍
20.	Most of my friends are better at math than I am.	❍	❍	❍	❍	❍
21.	It is important to get to know students who are different from me in their cultural and socio-economic backgrounds.	❍	❍	❍	❍	❍
22.	I spend a lot of time studying math.	❍	❍	❍	❍	❍
23.	I am good in music.	❍	❍	❍	❍	❍
24.	Computer skills are essential for my future success.	❍	❍	❍	❍	❍