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Learning Statistics using Concept Maps: Effects on Anxiety and Performance

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LEARNING STATISTICS USING CONCEPT MAPS: EFFECTS ON ANXIETY AND PERFORMANCE

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ABSTRACT

LEARNING STATISTICS USING CONCEPT MAPS:
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by Patrick F. Cravalho

The aim of this thesis was to study the use of concept mapping in an undergraduate statistics course in order to examine the effects on statistics anxiety and academic performance by means of a two-group quasi-experimental design. Two undergraduate statistics classes were recruited for this study with one serving as the treatment (concept map) group and one serving as the control (standard instruction) group. It was hypothesized that the use of concept mapping would decrease the statistics anxiety and improve the academic performance of students in the concept map group when compared with the control group. The statistics anxiety of the concept map group decreased more than that of the control group over the course of the semester, but the group differences in anxiety were not found to be statistically significant. The academic performance of both the concept map and control groups remained relatively stable throughout the course of the semester, and the groups did not significantly differ on academic performance measures. Significant differences were found between the concept map and control group on the interpretation anxiety subscale of the statistical anxiety measure used in this study and between the proficient and non-proficient concept map user scores on the computational section of the third academic performance measure. The study hypotheses were not supported. It is suggested that future research include less concept map training, more specific instruction for concept map creation, and investigation of particular student groups.

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Introduction

In general, anxiety can be defined as an unpleasant emotional reaction to a threatening situation (Cheung, 2006). There is also conventional agreement that anxiety is comprised of two components, trait anxiety and state anxiety. Schwarzer, Van de Ploeg, and Spielberger (1982) defined trait anxiety as stable, individual differences in proneness to anxiety and defined state anxiety as a transitory, emotional condition characterized by subjective, conscious feelings. One study found that trait anxiety coupled with test difficultly induces state anxiety in some undergraduate students (Head & Lindsey, 1983). In that study, students were faced with a test situation and those with higher trait anxiety exhibited significantly higher levels of state anxiety than did students with low trait anxiety. These results show that test anxiety is frequent in some undergraduate students.

Liebert and Morris (1967) suggested that test anxiety has two major mechanisms, *worry*, or cognitive concern over performance, and *emotionality*, the automatic arousal of anxiety in test situations. Wine (1971) speculated on the importance of the worry component with an attentional interpretation. She believed the adverse effects of test anxiety to be due to the division of attention between the self and the test. Wine suggested that high test-anxious students perform poorly because their attention is directed away from the test and directed towards self-evaluative ruminations. Students with high levels of test anxiety are believed to have trouble attending to the relevant parts of a test due to intrusive thoughts and emotional arousal, limiting their capacity to perform well (Easterbrook, 1959). Studies have shown that test anxiety has negative effects on academic performance (Sarason, 1960; Spielberger, 1966). In this regard, two anxiety-inducing academic topics that have received attention by researchers are mathematics (e.g., Adams & Holcomb, 1986; Betz, 1978; Dew, J. P. Galassi, & M. D. Galassi, 1984) and statistics (e.g., Blalock, 1987; Caine, Centa, Doroff, Horowitz, & Wisenbaker, 1978; Gaydosh, 1990; Lundgren & Fawcett, 1980; Schacht & Stewart 1990, 1991; Zeidner, 1991).

Math Anxiety, Test Anxiety, and Processing Efficiency Theory

Math anxiety is a negative reaction to situations involving numbers and mathematical calculations, which ranges from minor irritation to emotional and physiological disturbance (Ashcraft & Moore, 2009). One conceptualization of math anxiety is that it is a response to not only mathematical content, but a reaction to situations in which mathematical skills are evaluated, such as exams (Richardson & Woolfolk, 1980). This conceptualization is meant to separate math anxiety from test anxiety, to which math anxiety had previously been regarded as a subtype (Zettle & Raines, 2000). Research has shown math anxiety measures are more strongly related to each other than to the components of test anxiety (e.g., Dew, J. P. Galassi, & M. D. Galassi, 1983). Other research has shown consistent, significant correlations between measures of math anxiety and test anxiety among college students in psychology and statistics courses (Adams & Holcomb, 1986; Betz, 1978; Dew et al., 1984).

Zettle and Raines (2000) conducted a study utilizing a measure of trait anxiety, a measure of test anxiety, and a measure of mathematics anxiety to correlate math anxiety with test anxiety and trait anxiety in college algebra. Measures of all three anxieties were significantly correlated, but higher correlations were found between math and test anxiety, and math and trait anxiety than had been previously reported, with the relationship between math and test anxiety stronger than the relationship between math and trait anxiety. These results were unexpected, but can be explained in part by the inclusion of the Mathematics Anxiety Rating Scale (Richardson & Suinn, 1972), as this inventory included items assessing anxiety during math exams. Zettle and Raines concluded that maintaining a distinction between math and test anxiety is useful because individual differences, such as gender or self-efficacy, are associated with higher levels of math anxiety in individuals exhibiting co-morbid levels of test or trait anxiety. Research has shown that a relationship between math anxiety and performance exists (Adams & Holcomb, 1986, Ashcroft & Faust, 1994; Ashcraft & Kirk, 2001; Ma, 1999), showing that some students are concerned about the effects of anxiety on their grades.

Cates and Rhymer (2003) designed a study to show a stronger relationship between the math anxiety and math performance of undergraduate students. They found math anxiety to be related to math performance in a more complex fashion then what was previously shown. That is, they found that students with lower levels of math anxiety completed more basic mathematical operations (addition, subtraction, multiplication, division, and linear equations) correctly per minute than did students with higher levels of math anxiety. However, they found no differences between low and high math anxiety students in error rates of the problems completed, meaning that math anxiety is tied to learning fluency (the ability to quickly and efficiently perform a behavior correctly) rather than to overall performance accuracy (performance when time is not an issue for the student).

According to Eysenck and Calvo (1992), processing efficiency is inferred from performance effectiveness and anxiety can have adverse effects on both processing and performance. As reported by Eysenck (1982), much evidence exists indicating that task performance is affected by individual differences in trait and test anxiety in several differing situations. After conducting 24 experiments, the typical result Eysenck found was that high trait and test anxious individuals performed worse than did low trait and test anxious individuals when the task was difficult. Impaired performance also became more consistent under stressful conditions, when the task was difficult, and the performance gap widened between high trait and test anxious individuals and low trait and test anxious individuals. Processing efficiency theory was born out of this research, providing an explanation for the effects of state anxiety on performance. Eysenck and Calvo (1992) also speculated that this theory is most relevant to high anxiety in normal populations and test or evaluative stress conditions.

According to processing efficiency theory, worry about task performance impedes the storage of resources and the processing of one's working memory system. This point was illustrated by Ashcraft and Moore (2009), who elaborated on the vulnerability of working memory to the effects of math anxiety. In that study, math-anxious students reported trouble in remembering things during exams due to inner-worries and self-doubts about their math abilities. When these feelings are aroused, a significant decline in performance may occur, and this decline may worsen as math becomes more abstract, placing a heavier load on working memory (LeFevre, DeStefano, Coleman, & Shanahan, 2005).

Eysenck and Calvo (1992) also purposed that the sense of worry about task performance serves as motivation, which is exercised via the control system of one's working memory. The control system has two major functions, to monitor cognitive processes for efficiency problems and to introduce corrective resources and strategies to overcome any problems. The motivation compensates for performance impairments by allocating the use of additional resources or strategies. High-anxious individuals use such resources or strategies more frequently than do low-anxious individuals. Successful processing activities can increase available working memory capacity, leading to improvements in performance. Eysenck and Calvo (1992) concluded: (a) that state anxiety is associated with poor processing under exam conditions; and (b) that state anxiety affects performance based on the availability and utilization of additional resources and the task demands on working memory. The implications of these conclusions are relevant to undergraduate exam conditions, but may be more relevant to more anxiety-inducing subjects, such as statistics (Blalock, 1987; Caine et al., 1978; Gaydosh, 1990; Lundgren & Fawcett, 1980; Schacht & Stewart 1990, 1991; Zeidner, 1991).

Statistics Anxiety

Statistics anxiety is a particular form of performance anxiety marked by extensive worry, mental disorganization, and physiological arousal when confronted with statistics materials (Zeidner, 1991). According to Onwuegbuzie, Da Ros, and Ryan (1997), statistics anxiety is defined by four component anxieties, namely *instrument*-, *content*-, *interpersonal*-, and *failure*-anxiety. Instrument anxiety relates to feelings about one's ability to calculate statistical formulas. Content anxiety relates to how one feels about using and communicating personal statistics knowledge. Interpersonal anxiety relates to how one feels about interacting with an instructor or fellow students. Finally, failure anxiety relates to feelings about one's academic performance in a statistics class.

Whether statistics courses contribute to anxiety has been studied at various universities and settings over the years, with several researchers finding these classes to be among the most anxiety-inducing (Blalock, 1987; Caine et al., 1978; Gaydosh, 1990; Lundgren & Fawcett, 1980; Schacht & Stewart 1990, 1991; Zeidner, 1991). Introductory statistics courses are required for many college students, and many of these students perceive these classes in an extremely negative manner (Onwuegbuzie, 1997). Students with statistics anxiety often delay enrolling in courses related to their anxieties (Onwuegbuzie & Wilson, 2003). This avoidance and other procrastination behaviors, such as delaying assignments or delayed studying, can lead to lower academic performance for students in undergraduate courses that emphasize statistics and research methodology (Onwuegbuzie & Leech, 2003). Moreover, poor academic performance can affect whether or not students with statistics anxiety continue in their chosen program and attain a degree (Onwuegbuzie & Wilson, 2003). Onwuegbuzie (1998) found that as many as 80% of students with high statistics anxiety regard taking a statistics class as a major threat to degree attainment. Thus, statistics anxiety has a negative effect on learning (Onwuegbuzie & Seaman, 1995) and is the best predictor of academic achievement in statistics and research methodology courses (Onwuegbuzie & Leech, 2003).

Parallels between Math Anxiety and Statistics Anxiety

Zeidner and Safir (1989) theorized that statistics anxiety develops from a history of success and failure experiences in situations involving mathematics and is shaped by an overlap of affective, social, and cognitive factors. Watson, Kromrey, Lang, Hess, Hogarty, and Dedrick (2003) found that students' perception of statistics as heavily mathematical causes high amounts of anxiety in college. Another study found that psychology statistics students had higher levels of math anxiety than did math students (Morris, 1978). As it has been theorized for math anxiety, students' levels of statistics anxiety, and the learning and performance consequences due to that anxiety, are shaped by their personal background, prior educational experience, and motivational variables related to statistics courses taken (Hendel, 1980; Richardson & Woolfolk, 1980; Tobias, 1987). Math-anxious students avoid math coursework and college majors that require math (Ashcraft & Moore, 2009), a finding that is mirrored by statistics-anxious students who avoid statistics coursework and college majors that require statistics (Onwuegbuzie & Wilson, 2003). As has been shown with math anxiety, statistics anxiety is related to, but also distinguishable from, test anxiety because it includes one's response to statistics material in addition to one's response to statistics exams (Richardson & Woolfolk, 1980).

Zeidner (1991) conducted a study that investigated empirically salient commonalities between math anxiety and statistics anxiety. His data supported a two-factor structure for statistics anxiety composed of a statistics test anxiety component and a statistics content component. This structure corresponded well with data reported by Rounds and Hendel (1981) for a measure of math anxiety comprised of math test anxiety and numerical anxiety factors. Zeidner also hypothesized that statistics anxiety negatively correlates with math proficiency and self-efficacy and positively correlates with certain background experiences, such as math anxiety experience in high school. The data from Zeidner's study showed that perceived math ability may play a role in the level of statistics anxiety experienced, a finding that is consistent with previous research showing that low math self-esteem reinforces math anxiety (Smith, 1981). Zeidner suggested prior averse experiences with math, prior poor achievement in math, and low math self-efficacy as antecedent correlates of statistics anxiety, and these hypotheses were supported by his study. Finally, Zeidner found a weak relation between statistics anxiety and statistics course performance. Overall, Zeidner's study provides evidence that statistics anxiety mirrors math anxiety in a sample of social science students, and that statistics anxiety is a potential barrier to a successful college experience in studying statistics. The question then is how can we help students overcome their statistics anxiety and have an academically successful experience with college statistics? The answer may be to provide students with a cognitive study strategy that allows them to more accurately visualize and understand their internal thoughts about statistics.

Mental Models and Academic Performance

Streitz (1988) defined a mental model as a subjective, extremely personal knowledge representation. One may have an incomplete or unstable mental model, reflecting a partial or perhaps false understanding of a concept, or one may have an expert-like mental model, reflecting a complete and useful understanding of a concept (Hong, 1992). Mayer (1989) found that conceptual models, or words and diagrams that are intended to help students build mental models, could improve their recall of conceptual information. However, Mayer did not investigate if these recall improvements lead to improved performance. Mayer, Dyck, and Cook (1984) investigated the effects of mental models on performance after providing their participants with node training, which involved learning the conceptual underpinnings of key definitions relating to causal systems, and link training, which emphasized the main relations among the node concepts. They found that the mental model group recalled significantly more information about the main concepts and their relationships than did the control group.

Hong and O'Neil (1992) tested the effects of mental model strategies using students from an introductory statistics course. These researchers concluded that providing students with mental model strategies significantly facilitated understanding of the concepts and procedures relevant to hypothesis testing. In addition, instruction utilizing diagrammatic representation and building personal mental models facilitated the development of students' representational ability, thus enhancing their acquisition of knowledge.

Concept Maps as a Metacognitive Strategy

Concept maps represent a strategy for creating a diagrammatic representation of a metal model. As developed by Novak (1990), concept maps are representations of one's ideational framework, specific to a domain of knowledge. Concept maps include nodes that are filled with concept names or definitions and links that can be labeled with words that describe interconnections between the nodes (Afamasaga-Fuata'I, 2008). Links that include words form propositions, which are seen as units of psychological meaning, giving the concepts represented by the links an idiosyncratic connotation to the person who created the concept map (Novak, 1990).

According to Kinchin, Hay and Adams (2000), there are three basic concept map structures. These structures can be used for a range of instructional applications, such as creating a study guide or reading guide, outlining a research paper, or as a lecture supplement (Jacobs-Lawson & Hershey, 2002). A *spoke* map is a radial structure in which all the related subtopics are linked directly to the main topic, but are not linked to each other (see Figure 1).

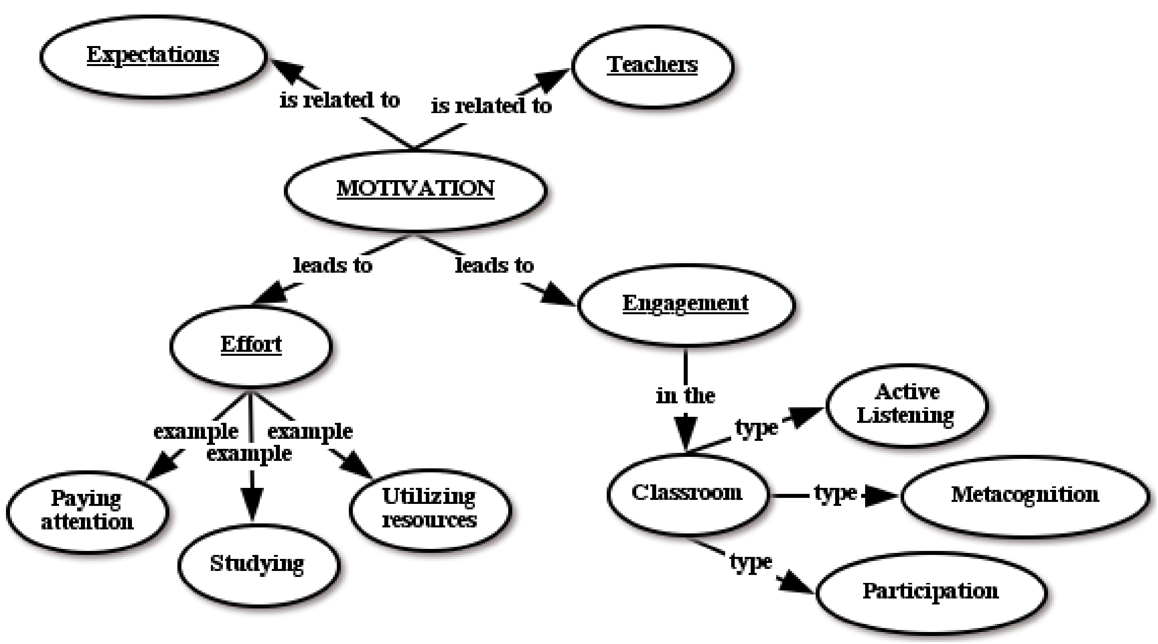

Figure 1. Example of a spoke concept map, with links, detailing factors relating to motivation.

A *chain* map contains a linear sequence of concepts where each idea is only linked to the concepts that come immediately before and after it (see Figure 2).

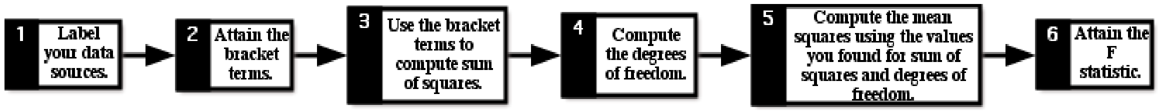

Figure 2. Example of a chain concept map detailing the steps in calculating an analysis of variance.

A *net* map is a highly integrated and hierarchical network of concepts (see Figure 3).

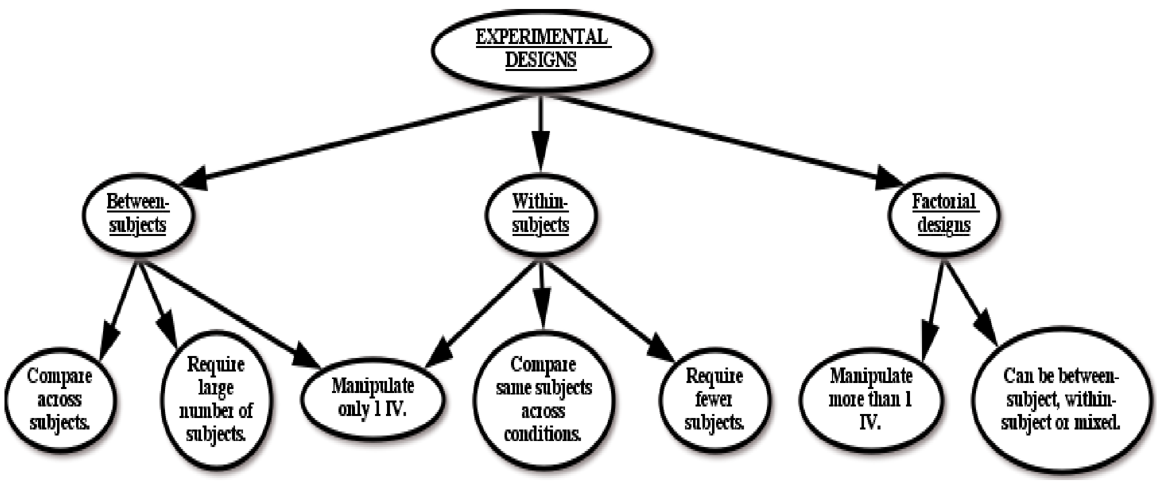

Figure 3. Example of a net concept map, detailing the different types of experimental research designs.

The use of concept mapping is associated with the constructivist view of learning. Novak (1993) summarized this view as the belief that individuals construct and reconstruct the meaning of what they observe. Thus, according to the constructivist view, knowledge is not discovered, but is created. Novak (1990) developed the technique of concept mapping based on the work of David Ausubel (1968), whose assimilation theory stressed using prior knowledge to learn new concepts. Concept maps can be described as a form of metacognitive learning, as they are a strategy that enables the understanding of one's existing knowledge (Novak, 1990). Meaningful learning is the process in which individuals engage when relating new knowledge to existing ideas in a non-verbatim, non-arbitrary, and substantive fashion (Ausubel, 1968). In principle, concept maps help learners to engage in this process, which is described as the process underlying knowledge acquisition and construction, and consequently the foundation for constructivism (Novak, 1990). Concept maps are a powerful metacognitive strategy for enabling meaningful learning because they can be applied to any subject and at any level of schooling.

Concept Maps and Statistics Anxiety

Strategies for alleviating statistics anxiety, such as explaining statistics concepts to other people (Pan & Tang, 2005), using a humorous teaching style, or addressing the anxiety (Pan & Tang, 2004) are already in use today. These strategies are useful, but they only address one component of statistics anxiety (i.e., interpersonal anxiety), whereas the use of concept maps can provide a strategy for addressing all four components of statistics anxiety (i.e., instrument, content, interpersonal, and failure anxieties). Concept maps enable students to show their understanding of statistical calculations and obtain feedback on possible misconceptions (i.e., instrument and content anxieties). Concept mapping also gives students a tangible product that they can share with instructors and other students to promote their ideas and answer their questions (i.e., interpersonal anxiety). A concept map is also a modifiable study aid for exams and other course assignments (i.e., content and failure anxieties). Creating concept maps can also be a collaborative process, which creates opportunities for students to display their understanding of statistics to another person at an in-depth level and then to synthesize that shared knowledge into a visual model (i.e., content, interpersonal, and failure anxieties). Concept maps provide a complete approach to addressing statistics anxiety and consequently to improving academic performance in a statistics course.

Concept maps have been shown as an effective metacognitive strategy for reducing the anxiety of students at different levels of education. For example, the use of concept maps was found to reduce anxiety levels in high school students (Jegede, Alaiyemola, & Okebukola, 1990) and undergraduate students (Okebukola & Jegede, 1989) taking biology classes. These two studies show that concept maps can alleviate anxiety about learning material that is perceived as difficult to learn. Statistics is another set of material that is perceived as difficult to learn (Lackey, 1994). It is very common for a student to have a limited understanding of mathematics, with this understanding relating mostly to computational skills with little to no relation to conceptual understanding (Perry, 2004). Such an incomplete understanding provides no mental framework for organizing one's mathematical knowledge, which may make it difficult for the student to remember what was learned in the past. Given that statistics anxiety is likely to develop from situations involving mathematics (Zeidner & Safir, 1989), it seems likely that the same memory difficulties seen in math anxiety also apply to statistics knowledge. Concept mapping is a metacognitive strategy that may help undergraduate students remember more conceptual information about statistics.

Kesici and Erdogn (2009) found that self-regulated learning (metacognitive) strategies are predictors of college students' math anxiety. Specifically, they found that students who do not consider strategies for elaboration of learning as important have a decreased probability of academic success in math courses. This implies that a failure to learn math or statistics stems from the use of inappropriate learning strategies, so it is recommended that students develop more appropriate learning strategies in order to succeed in academics (Linnenbrink & Pintrich, 2002). This recommendation is supported by findings showing the use of metacognitive strategies, such as concept mapping, to lead to better performance in college students (Metallidou & Viachou, 2007).

Concept Maps and Academic Performance

Lavigne (2005) found that concept maps are useful in revealing the relationships between statistical concepts that are often not articulated by statistics faculty. In this study, such articulation allowed the creators of the concept maps to clarify their ideas and also allowed for an observer to evaluate the creators' amount of underlying knowledge. Research has also shown that concept maps allow the identification of misconceptions held by the creator (McClure, Sonak, & Suen, 1999). Employing the use of concept maps could make statistical concepts more salient to students, helping them to gain a more complete, organized understanding of statistical theory and to know when to properly apply relevant principles. Generative concept mapping (allowing students to create their own maps) supports the effective organization of knowledge (Lee & Nelson, 2005), allowing learners to solve structured problems more efficiently than traditional concept mapping methods (giving students a completed concept map). This benefit of concept maps can improve student performance for those who skip steps or make minor mistakes when calculating a formula or solving a challenging problem.

Torre, Kromrey, Lang, Hess, Hogarty, and Dedrick (2007) found concept mapping to be an effective learning method and teaching methodology for medical students. In their experiment, the use of concept maps facilitated knowledge integration and critical thinking, which, in turn, fostered positive connections between theory and practice. Like the medical students in Torre and colleagues study, statistics students have trouble understanding the theoretical basis of the material they study, so statistics anxiety is prevalent among students enrolled in statistics courses (Onwuegbuzie & Wilson, 2003). Bartz, Amato, Rasor, and O'Neil-Rasor (1981) found evidence to support the relationship between statistics anxiety and theoretical understanding of statistics, as they found that lowering statistics students' anxiety led to an increase in statistics knowledge. Studies have shown that the primary benefit of a concept map accrues to the person who creates the map, not the person evaluating the map (e.g., Bogden, 1977; Cardemone, 1975). This being so, the intention of the present study was to teach statistics students how to create their own maps so they receive the benefits directly. By providing statistics students with a strategy for understanding statistics theory, we should be able to alleviate their statistics anxiety and in turn improve their academic performance in a statistics course.

Study Aims and Predictions

The aim of the current study was to empower statistics students to gain an individualized understanding of statistics theory, in order to ease their statistics anxiety.

According to processing efficiency theory (Eysenck & Calvo, 1992), anxiety can have negative effects on performance, thus the reduction of statistics anxiety should lead to less negative effects on performance and, in turn, improved exam scores. By studying the use of concept mapping in an undergraduate statistics course we could examine the effect of concept map use on statistics anxiety and performance.

Two undergraduate statistics classes were recruited for this study with one serving as the treatment (concept map) group and one serving as the control (i.e., standard instruction) group. We hypothesized that the use of concept mapping would decrease the statistics anxiety of students in the concept map group compared to those in the control group. We also hypothesized that the use of concept mapping would improve the academic performance of students in the concept map group, resulting in significantly better exam performance compared to the control group.

Methods

Participants

In total, 101 undergraduate students attending San José State University (SJSU) were recruited from two lower-division, introductory statistics classes to participate in this study. Of these participants, 75 (51 female, 24 male) completed the demographics questionnaire. Based on the demographics data, the average age was 19.34 (SD = 2.53), with ages ranging between 18 and 32. The participants were a less experienced group in terms of academic standing, with freshman (35) and sophomores (16) making up two thirds of the sample and the remaining third consisting of juniors (13) and seniors (11). A wide range of ethnicities including White (27%, n = 20), Black (7%, n = 5), Hispanic (19%, n = 14), Asian (31%, n = 23), American Indian (1%, n = 1), as well as participants of mixed heritage (16%, n = 12) were present in this sample, mirroring the diverse ethnic composition of SJSU students. IRB approval was obtained prior to the recruitment of participants. All standards for ethical treatment of participants set forth by the APA, including obtaining informed consent and maintaining confidentiality, were followed at all times during this study.

Design

The study utilized a 2 x 3 mixed factorial design, with concept map usage as the between-subjects factor and time of measurement as the within-subjects factor, to examine the effect of concept mapping on statistics anxiety. The Statistics Anxiety Rating Scale (STARS; Cruise, 1985) was used to measure the statistics anxiety present in the experiment participants. A 2 x 4 mixed factorial design, with concept map usage as the between-subjects factor and time of measurement as the within-subjects factor, was used to examine the effect of concept mapping on academic performance. The four module exams administered during the semester were used to measure the academic performance of the experiment participants.

Setting and Apparatus

The study took place in two standard university classrooms with maximal occupancies between 48 and 62 people. The concept map room was furnished with rows of single-occupancy student desks arranged so that students sat behind one another. The control room was furnished with long tables arranged in rows and oriented in parallel to the front of the class such that students sat side-by-side. Both rooms were equipped with large whiteboards and overhead LCD projectors used for slide presentations. The classroom whiteboards (with markers) and projectors were utilized during classroom activities. The concept map class was held weekly on Monday and Wednesday from 9:00 a.m. to 10:15 a.m. and the control class was held weekly on Tuesday and Thursday during the same time period. The same professor taught each class, with the participants being recruited from each class, by the instructor, on a volunteer basis.

Materials

Extra credit assignments. Six concept map training worksheets were assigned only to the concept map class between the beginning and 8-week point of the 16-week semester. These worksheets included matching words and phrases to the corresponding concept map node or link (see Appendix A). Inspiration software (V. 8; Inspiration® Software, Inc., Beaverton, OR) was used to create the concept maps for the worksheets.

The participants in the concept map class were also asked to create four original concept maps between the 8-week point and end of the 16-week semester. The concept map class participants received extra credit for each completed concept map worksheet and each completed map of the first three original concept map assignments. A more detailed discussion of the concept map worksheets and original map assignments will be presented in the Procedure section below.

Over the course of the entire 16-week semester, the participants in the control class were assigned seven crossword puzzles containing statistics terms from the assigned textbook (Gravetter & Wallnau, 2008). The crosswords were supplemental materials that came with the textbook. The control class participants were also asked to complete two additional online tutorial assignments that were created by the professor. For these assignments, the students in the control class had to apply statistics material learned in class to real world situations and then answer brief questions related to the situation. The control class participants received extra credit for each completed crossword puzzle and each completed online tutorial assignment. The first six crossword puzzles were assigned during the first two class modules. The final crossword puzzle and the two online tutorial assignments were completed during the third class module.

Demographics. Each class had the first two weeks of the semester to complete a demographics questionnaire. This measure asked the participants to record their sex, age, race, college major and minor, academic standing, their number of completed college units, prior undergraduate statistics or research methodology course experience and high school mathematics and statistics experience (see Appendix B).

Concept map usage. The concept map training for the concept map class ended right before the 8-week point of the semester. At this point, the participants in the concept map class completed a concept map usage questionnaire containing 14 questions. These participants also completed a concept map usage questionnaire, containing 11 questions, at the end of the semester. Each of these inventories was based on a 5-point Likert-type agreement scale. The questions were regarding topics such as how many occasions per week the students used concept mapping techniques inside and outside of class, how useful they felt the concept map lessons and activities were for learning statistics, which type of maps they preferred (spoke, chain, or net) for statistics concept maps, how useful they felt the maps were for increasing their theoretical understanding of statistics, and how useful they felt the maps were for decreasing their anxiety (see Appendices C and D).

Statistics Anxiety Rating Scale (STARS). Each class completed the STARS on three occasions, at the beginning, midpoint, and end of the semester. This inventory is based on a 5-point Likert-type scale and has 51 items. The first 23 questions (part 1) pertain to situations associated with statistics anxiety. The response scale for part 1 was anchored with a 1 (*No Anxiety*) and a 5 (*Very Much Anxiety*) and was based on level of anxiety. The final 28 questions (part 2) pertain to statistics, but are not related to situations associated with statistics anxiety. The response scale for part 2 was also anchored with a 1 (*Strongly Disagree*) and a 5 (*Strongly Agree*), but was based on level of agreement rather than level of anxiety.

Each part of the STARS includes three subscales of questions, meaning a total of six subscales are included in this inventory. Part 1 includes the *Interpretation Anxiety* (11 items, e.g. “Trying to decide which analysis is appropriate for your research project.”), *Test and Class Anxiety* (8 items, e.g. “Doing the final examination in a statistics course.”), and *Fear of Asking for Help* (4 items, e.g. “Going to ask my statistics teacher for individual help with material I am having difficulty understanding.”) subscales. Part 2 includes the *Worth of Statistics* (16 items, e.g. “I don’t see why I have to clutter up my head with statistics. It has no significance to my life work.”), *Computational Self-concept* (7 items, e.g. “Since I’ve never enjoyed mathematics, I don’t see how I can enjoy statistics.”), and *Fear of Statistics Teachers* (5 items, e.g. “Statistics teachers are so abstract they seem inhuman.”) subscales.

The STARS inventory is the most utilized measure of statistics anxiety and the only one that has been subjected to studies of validity (Onwuegbuzie & Wilson, 2003). Mji and Onwuegbuzie (2004) found this scale to have acceptable internal consistency, reliability coefficients, and construct validity as a whole and for each subscale. According to Mji and Onwuegbuzie, scores on the STARS inventory have been correlated with scores on the Mathematics Anxiety Scale (Betz, 1978), yielding a large statistically significant correlation coefficient, r = .76 ($p < .01$), which provides evidence for the concurrent validity of the STARS inventory. Onwuegbuzie (1999) reported coefficient alpha ranging from .78 (Worth of Statistics) to .84 (Test and Class Anxiety), with a median of .80, on the six subscales of the STARS inventory, which shows high internal consistency.

For this study, a single STARS score (out of 250) was calculated for each participant at each time of measurement by summing the responses to each question making up the STARS scale. A part 1 score (out of 110) was also calculated for each participant at each time of measurement by summing the responses to each question making up the part 1 subscales. Finally, a part 2 score (out of 140) was calculated for each participant at each time of measurement by summing the responses to each question making up the part 2 subscales. The higher the score, on any of these measures, the more anxiety a respondent was reporting.

SJSU Blackboard. The demographics, concept map usage, and STARS questionnaires were all posted on the SJSU Blackboard learning management system (Blackboard®, Inc., Washington, DC). This system allows students to monitor their grades, discuss course topics in online forums, and to download class materials, among other academic functions. This website was accessible to all of the participants. Each questionnaire was created using the survey tool found on the instructor page. It was the responsibility of each student to log on to the SJSU Blackboard webpage and complete each questionnaire.

Concept map rubric and quantitative analysis. The experimenter created a qualitative scoring rubric (see Appendix E) to be used in conjunction with a quantitative analysis of concept map structure. The rubric was developed through examining other concept map rubrics, identifying useful segments from those rubrics, and finally synthesizing ideas from those segments into a new rubric. This rubric was separated into four sections of evaluation: *Content Organization*, *Structure*, *Communication*, and

Overall Presentation. For the Content Organization section, each map was assessed on overall organization, format, and appropriateness of main topic and sub-topics. For the Structure section, each map was assessed on the clearness of nodes and links. For the Communication section, each map was assessed on the overall effectiveness of the map structure in communicating the inherent relationships between the main topic and sub-topics. For the Overall Presentation section, each map was assessed on the overall level of discernible, understandable information presented in the map. Between 0 and 3 points were given for each section and then each section point total was added up to form a total rubric score, making 12 points the maximum score possible. The final structure of this new rubric included sections covering ideas addressed in each of the other rubrics that were examined, while leaving out ideas that were not as widely addressed. This method was used in order to ensure the face validity and content validity of the new rubric.

For the quantitative analysis of concept map structure, the number of components (nodes, links, etc.) was used as the basis for assigning a score to each map (Kinchin, Hay & Adams, 2000). For our analysis, we counted the number of nodes, links, levels of differentiation between concepts (or branches), pictures, colors, and statistical formulas, and added those numbers together to form a total quantitative score. A point was also awarded for using the correct concept map structure, because two of the map assignments requested the use of the net or spoke structure rather than the chain structure.

Academic performance. The academic performance of all the participants was measured four times over the course of the semester, with an exam at the end of each course module. Each exam consisted of two parts, with one section containing 25 multiple-choice questions and a computational section typically consisting of a vignette followed by five to seven questions requiring the student to apply and compute the statistical procedures taught during that module. The multiple-choice questions were written to assess the students' conceptual and/or applied knowledge of the statistical concepts covered within a module. Very few simple recall-type questions (e.g., recognizing definitions, formulas, etc) were used in the exams. These questions were created by the instructor and were drawn from both the textbook and class lectures. A single exam score, out of 50, was calculated for all participants by summing the correct responses to each question making up an exam, with a separate score being calculated at each of the four times of measurement. A conceptual exam score, out of 25, was calculated for all participants by summing the correct responses to each question making up the multiple-choice section, with a separate score being calculated at each of the four times of measurement. A computational exam score, out of 25, was calculated for all participants by summing the correct responses to each question making up a vignette section followed by five to seven questions requiring the student to apply and compute the statistical procedures taught during that module section, with a separate score being calculated at each of the four times of measurement. The higher the total, conceptual, or computational score, the more total, conceptual, or computational understanding of statistics knowledge the participant was demonstrating.

Procedure

Experiment introduction. All of the participants shared the same professor, who taught two introductory statistics sections during the same semester. On the first day of class for both the concept map group and the control group, the experimental procedures were explained and informed consent was obtained from the students from each group that elected to participate in the study. In the concept map class only, the experimenter gave an introductory concept map presentation, after the professor's lecture. This introductory presentation included background information on the cognitive theories developed by Ausubel (1968), the underlying theory of concept mapping developed by Novak (1993), and examples of the three types of concept maps outlined by Kinchin, Hay, and Adams (2000). The initial presentation slides allowed for the examination of sample maps, included information about the different parts of a concept map, the function of each part, and how the flow of ideas about a particular topic can be conveyed using a concept map. Each group was given the first few weeks of the semester to complete the demographics questionnaire and the initial STARS inventory.

This study involved two groups, but the control group did not receive any concept map training or any additional study skill instruction. The professor followed the same curriculum for each group, and the experimenter conducted the concept map presentations and activities, handed out and explained the concept map worksheets, and explained the concept map usage surveys for the concept map group only. The curriculum consisted of lessons on descriptive statistics during module one, lessons on probability and sampling during module two, lessons on hypothesis testing and the t statistic during module three, and lessons on analysis of variance (ANOVA) during module four.

Concept map training. Over the course of the first 8 weeks of the semester (modules one and two), the concept map group received instructions on how to generate concept maps. To train the concept map class in creating and using concept maps, sample concept maps were presented using standard presentation software. This class listened to five concept map presentations, each lasting between 5 and 10 min., which included the modeling of techniques for creating concept maps by the experimenter. During this time, this class also participated in five concept map activities, creating maps individually twice and creating maps as a group three times. Students created concept maps for *z*-scores, standardizing distributions, probability, central limit theorem, and standard error on the mean. For an individual training activity, each student created a concept map, and then volunteers would draw their maps on the whiteboard and explain them to the rest of the class. For a group training activity, the students formed a group of three or four and created a concept map as a team. Then volunteers from some of the teams drew their group maps on the whiteboard and explain them to the rest of the class.

The lectures and activities covered the following topics; (a) brainstorming ideas using concept maps, (b) using concept maps as a memory aide, (c) summarizing a topic using concept maps, (d) illustrating a step by step process using a concept map, (e) using concept map links to convey ideas, (f) comparing topics using concept maps, and (g) using concept maps to review for an exam. The concept map participants also completed six concept map worksheets, three covering topics from the first module and three covering topics from the second module. The concept map worksheet topics were types of data, frequency distributions, measures of central tendency, *z*-scores, probability, and central limit theorem. After the first concept map worksheets had been turned in, the experimenter reviewed the assignment with the entire concept map class.

During the class period before the first exam, there was also an informal, anonymous evaluation conducted to check how well the participants in the concept map class understood concept maps. The experimenter asked the participants to answer yes or no to the following statements: (a) “I understand what a concept map is,” (b) “I understand the different types of concept maps,” (c) “I understand when to use each type of concept map,” (d) “I use concept maps to organize my notes in class,” and (e) “I use concept maps to organize my materials outside of class.” The experimenter also made the following open-ended request of the students, “Write down any questions that you have regarding concept maps.” The participants were then handed in their responses without writing down their names. After reviewing the responses, the experimenter created a concept map review sheet, specifically addressing all of the questions posed by the concept map class. This sheet was then posted on the concept map group Blackboard page, for the participants in that group to download and review. The concept map training portion of the experiment ended with the second module exam. At the midway point of the semester, after the second module, both the concept map and the control groups completed a second STARS inventory. Also at this time, the concept map group completed the first concept map usage questionnaire.

Original concept maps. Over the course of the second 8 weeks of the semester (modules three and four), the concept map group received no further instruction and completed only two group concept maps activities. The topics of the two group activities were one- and two-tailed hypothesis tests and the independent samples *t* test. Each participant also created four original concept maps, with two covering topics from the third module and two covering topics from the forth module. The concept map topics were hypothesis testing, the *t* statistic, estimation, and ANOVA. After the first original concept map had been turned in, the experimenter reviewed the assignment with the entire concept map group during class time.

The experimenter used a qualitative rubric and a quantitative analysis of concept map structure to assess the four original concept maps created by the concept map group participants. For the hypothesis testing and ANOVA concept map assignments, the only requirement was that the students created either a spoke or net type map. Creating a chain map was not permitted for these assignments because this type of map does not allow for various levels of differentiation (i.e. it can only describe a sequence of events). There were no requirements for the *t* statistic or estimation maps because these concepts do not contain as many levels of differentiation as the topics of hypothesis testing and ANOVA. At the end of the semester, both the concept map and the control groups completed a third and final STARS inventory. The concept map group also completed a second, modified concept map usage questionnaire. All of the concept map worksheets and original concept maps were returned to the concept map group participants.

Results

Problematic Data

In preparing the demographics and concept map usage data for analysis, an uncorrectable error in collection was detected. These questionnaires were created as anonymous surveys and posted on the SJSU Blackboard system for the courses involved in this study. It was the belief of the researchers that the survey set up would allow the tracking of each participant's assigned code number, while keeping only their name hidden. This did not turn out to be the case, as the SJSU Blackboard system kept the information collected from each participant completely anonymous. We attempted to recover the identifying data, but all our attempts proved fruitless. Consequently, we were unable to identify individual demographic, concept map usage, and anxiety data for the study participants. As such, we were unable to use these data to conduct within group analyses as originally proposed.

In addition, the data collected using the STARS surveys posted on the SJSU Blackboard system was found to be problematic in the same way as the demographics and concept map usage data. However, we were still able to include these data in the group analyses conducted, as the STARS data for the concept map and control groups was separated by each courses' individual Blackboard webpage. This data error prevented us from examining individual cases from the STARS data to see if any interactions with the other variables existed.

Statistics Anxiety Findings

STARS reliability. Cronbach's alpha (α) was used to estimate the reliability of the STARS scale items. The subscale yielding the lowest alpha was Fear of Statistics Teachers (α = .75), and the subscale yielding the highest alpha was Worth of Statistics (α = .92). The remaining four subscales ranged between these low and high points, beginning with Fear of Asking for Help (α = .82), then Interpretation Anxiety (α = .85), next Test and Class Anxiety (α = .86), and finally Computation Self-Concept (α = .87). All of these estimates indicate acceptable internal consistency for the STARS subscales (Nunnally, 1994).

Overall statistics anxiety. At the beginning of the semester, the concept map group (M = 123.73, SD = 22.82, n = 41) and the control group (M = 122.19, SD = 21.24, n = 31) demonstrated practically equal overall anxiety scores. Then, at the midpoint of the semester, the concept map group (M = 109.70, SD = 23.52, n = 30) produced an overall 14-point drop in anxiety score, while the control group (M = 118.56, SD = 25.25, n = 34) produced an approximate 4-point drop in anxiety score. Each group maintained about the same level of anxiety until the end of the semester, with the concept map group overall score (M = 110.31, SD = 24.35, n = 35) increasing slightly more than the control group overall score (M = 118.95, SD = 23.88, n = 41). Figure 4 shows the patterns of STARS scores over the semester for each condition.

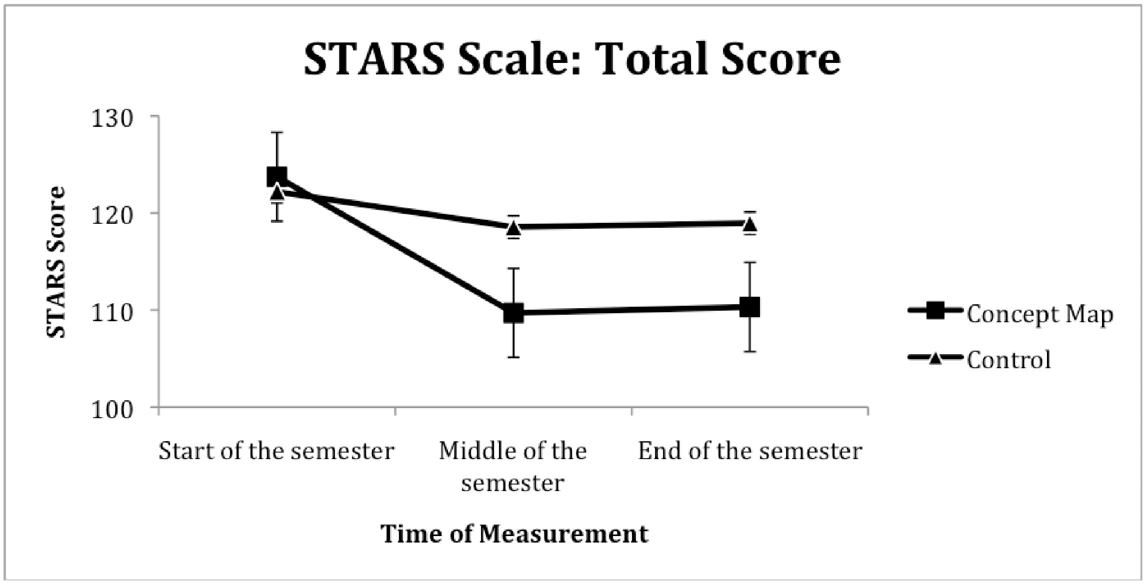

Figure 4. Mean STARS scores for the concept map and control groups. *Note.* Error bars represent +/-1SE.

A mixed analysis of variance was used to analyze the overall (parts 1 and 2 combined) STARS data, with time as a repeated measures factor and the experimental conditions as a between-subjects factor. A significant decline in anxiety scores was observed over time for both the concept map and control groups, $F(2, 94) = 3.25$, $p = .043$, $\eta^2 = .063$, meaning the concept map and control group each felt less anxiety as the semester progressed. However, there was no main effect of treatment condition (i.e., concept mapping vs. control) on anxiety, $F(1, 47) = 0.20$, $p = .651$, $\eta^2 = .004$, nor was there a significant interaction between the two groups on anxiety over time, $F(2, 94) = 1.20$, $p = .305$, $\eta^2 = .023$.

STARS part 1: Statistical anxiety. At the beginning of the semester, the concept map group ($M = 62.95$, $SD = 15.02$, $n = 42$) and the control group ($M = 63.33$, $SD = 12.48$, $n = 33$) demonstrated practically equal levels of anxiety. Then, at the midpoint of the semester, the concept map group (*M* = 56.00, *SD* = 14.12, *n* = 30) produced an overall 9-point drop in anxiety score, whereas the control group (*M* = 62.72, *SD* = 15.08, *n* = 35) maintained about the same level of anxiety. Each group maintained about the same level of anxiety until the end of the semester, with the concept map group overall score (*M* = 55.72, *SD* = 15.02, *n* = 36) decreasing slightly less than the control group overall score (*M* = 61.59, *SD* = 15.36, *n* = 41). Figure 5 shows the patterns of statistics anxiety subscale scores over the semester for each condition.

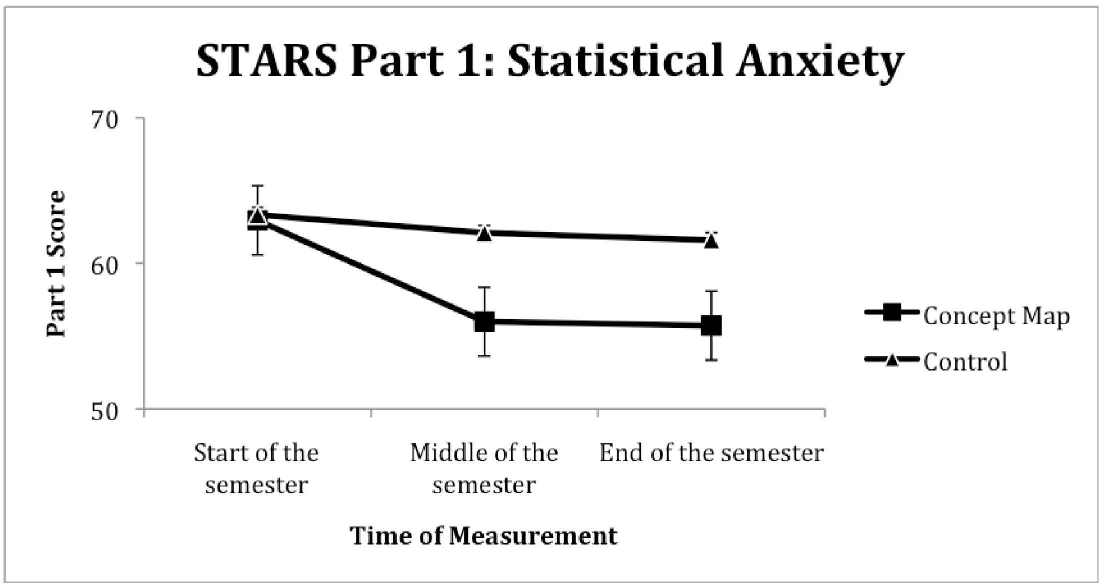

Figure 5. Mean STARS part 1 scores for the concept map and control groups.
Note. Error bars represent +/-1SE.

A mixed analysis of variance was used to analyze part one of the STARS scale data, with time as a repeated measures factor and the experimental conditions as a between-subjects factor. There was no significant main effect of time for this measure, $F(2, 102) = 2.61$, $p = .078$, $\eta^2 = .048$, nor was there a significant main effect of group, $F(1, 51) = 1.43$, $p = .236$, $\eta^2 = .0005$. Also, no significant interaction was identified between the two groups on part one of the STARS, $F(2, 102) = 0.66$, $p = .518$, $\eta^2 = .012$. Collectively these analyses show that concept mapping did not have a significant effect on the Interpretation Anxiety, Test and Class Anxiety, or Fear of Asking for Help forms of statistics anxiety.

STARS part 2: General statistics. At the beginning of the semester, the concept map group ($M = 61.29$, $SD = 19.06$, $n = 41$) demonstrated more general statistics anxiety than did the control group ($M = 59.27$, $SD = 14.31$, $n = 33$). Then, at the midpoint of the semester, the concept map group ($M = 53.28$, $SD = 16.28$, $n = 32$) produced an overall 8-point drop in anxiety score, whereas the control group ($M = 55.71$, $SD = 17.07$, $n = 35$) produced about a 4-point drop in anxiety score. At the end of the semester, the concept map group ($M = 54.31$, $SD = 19.31$, $n = 36$) anxiety level increased by a point, and the control group ($M = 57.37$, $SD = 17.97$, $n = 41$) anxiety level increased by about 2 points. Figure 6 shows the patterns of general statistics subscale scores over the semester for each condition.

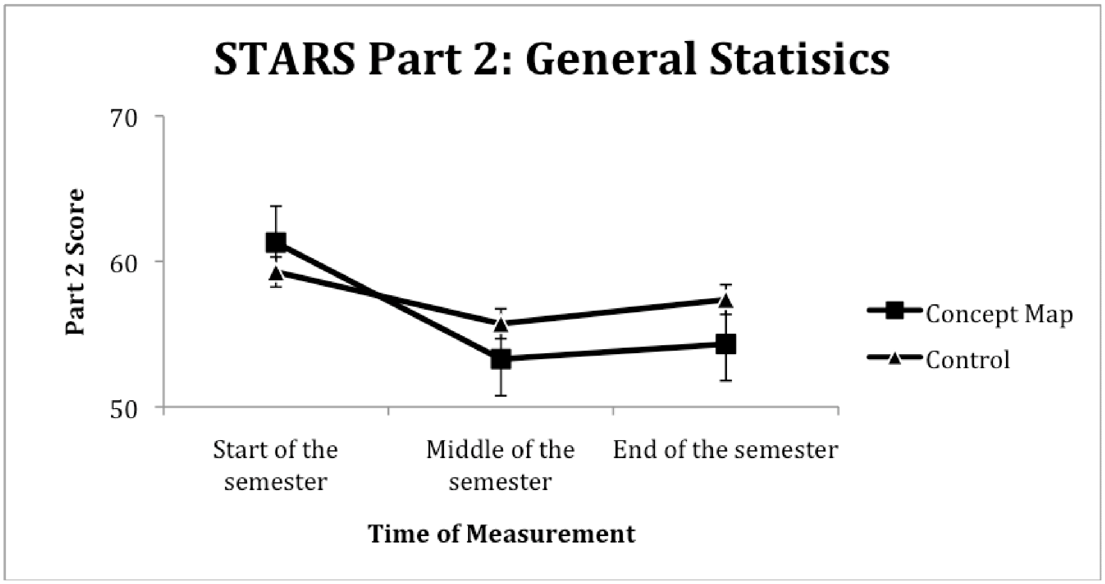

Figure 6. Mean STARS part 2 scores for the concept map and control groups.
Note. Error bars represent +/-1SE.

A mixed analysis of variance was used to analyze part two of the STARS scale data, with time as a repeated measures factor and the experimental conditions as a between-subjects factor. No significant main effect of time was found for this measure, $F(2, 98) = 2.05$, $p = .133$, $\eta^2 = .039$, nor was there a significant main effect of group, $F(1, 49) = 0.00$, $p = .933$, $\eta^2 = .000006$. Also, no significant interaction was identified between the two groups on part two of the STARS, $F(2, 98) = 1.38$, $p = .255$, $\eta^2 = .026$. Collectively these analyses show that concept mapping did not have a significant effect on the Worth of Statistics, Computation Self-Concept, or Fear of Statistics Teachers forms of statistics anxiety.

STARS subscales. At the beginning of the semester, the concept map group ($M = 27.40$, $SD = 7.36$, $n = 42$) demonstrated about a point less interpretation anxiety than did the control group ($M = 28.45$, $SD = 7.08$, $n = 33$). Then, at the midpoint of the semester, the concept map group (*M* = 25.52, *SD* = 6.05, *n* = 29) produced about a 2-point drop in anxiety score, and the control group (*M* = 28.49, *SD* = 6.89, *n* = 35) maintained about the same level of interpretation anxiety. At the end of the semester, the concept map group's (*M* = 24.31, *SD* = 7.00, *n* = 36) anxiety level decreased by a little more than a point, where the control group (*M* = 28.50, *SD* = 7.37, *n* = 40) again maintained about the same level of interpretation anxiety. For the Interpretation Anxiety subscale there were significant differences found between the two groups, confirming an effect of concept mapping on this form of statistics anxiety, $F(1, 60) = 8.24$, $p = .006$, $\eta^2 = .003$. No other subscale displayed a main effect of group, specifically Test and Class Anxiety, $F(1, 58) = 3.76$, $p = .057$, $\eta^2 = .001$, Fear of Asking For Help, $F(1, 61) = 0.51$, $p = .474$, $\eta^2 = .0003$, Worth of Statistics, $F(1, 62) = 0.91$, $p = .341$, $\eta^2 = .0003$, Computational Self-Concept, $F(1, 62) = 0.18$, $p = .672$, $\eta^2 = .0001$, and Fear of Statistics Teachers, $F(1, 63) = 2.10$, $p = .152$, $\eta^2 = .001$. Figure 7 shows the patterns of Interpretation Anxiety scores over the semester for each condition.

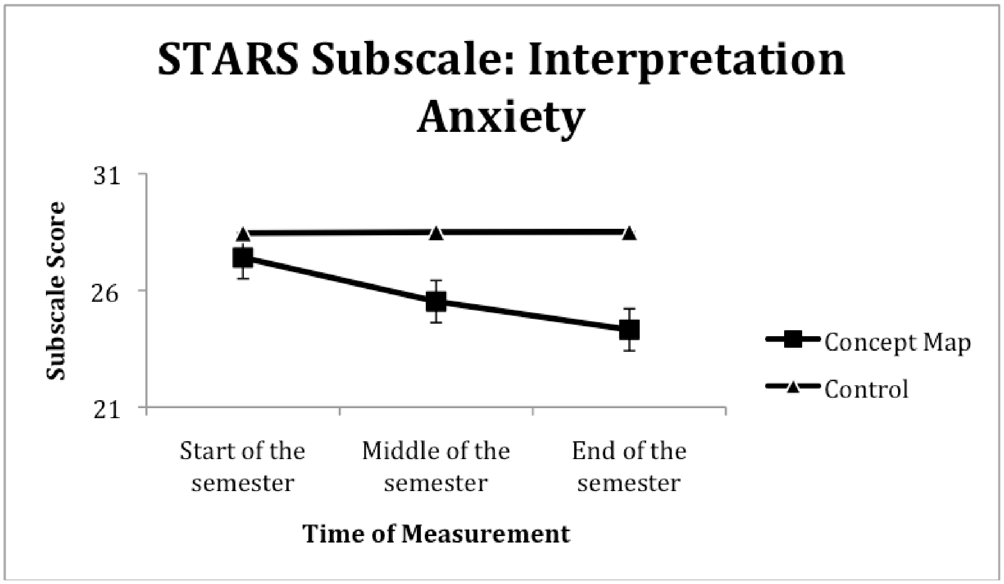

Figure 7. Mean Interpretation Anxiety scores for the concept map and control groups. *Note*. Error bars represent +/-1SE.

At the beginning of the semester, the concept map group (M = 9.85, SD = 3.95, n = 41) and the control group (M = 9.91, SD = 4.01, n = 33) demonstrated practically equal amounts of Fear of Statistics Teachers anxiety. Then, at the midpoint of the semester, the concept map group (M = 7.84, SD = 2.92, n = 32) produced about a 2-point drop in anxiety score, where the control group (M = 8.66, SD = 3.46, n = 35) produced a little more than a 1-point drop in anxiety score. At the end of the semester, the concept map group (M = 7.89, SD = 2.71, n = 36) and the control group (M = 8.76, SD = 3.36, n = 41) maintained about the same level of anxiety as measured during the midpoint of the semester. For the Fear of Statistics Teachers subscale there was a significant main effect of time, $F(2, 126) = 4.49$, $p = .013$, $\eta^2 = .066$, but no significant differences were identified between the two groups on this subscale over time, $F(2, 126) = 0.07$, $p = .928$, $\eta^2 = .001$. No other subscale displayed a main effect of time, specifically Test and Class

Anxiety, $F(2, 116) = 1.20$, $p = .302$, $\eta^2 = .020$, Interpretation Anxiety, $F(2, 120) = 1.15$, $p = .318$, $\eta^2 = .018$, Fear of Asking For Help, $F(2, 122) = 2.60$, $p = .078$, $\eta^2 = .040$, Worth of Statistics, $F(2, 124) = 0.22$, $p = .797$, $\eta^2 = .003$, and Computational Self-Concept, $F(2, 124) = 1.88$, $p = .156$, $\eta^2 = .029$. No other subscale displayed a significant interaction between the two groups, specifically Test and Class Anxiety, $F(2, 116) = .376$, $p = .687$, $\eta^2 = .006$, Interpretation Anxiety, $F(2, 120) = 1.01$, $p = .365$, $\eta^2 = .016$, Fear of Asking For Help, $F(2, 122) = 0.70$, $p = .494$, $\eta^2 = .011$, Worth of Statistics, $F(2, 124) = 0.22$, $p = .796$, $\eta^2 = .003$, and Computational Self-Concept, $F(2, 124) = 0.11$, $p = .895$, $\eta^2 = .001$. Figure 8 shows the patterns of Fear of Statistics Teachers scores over the semester for each condition.

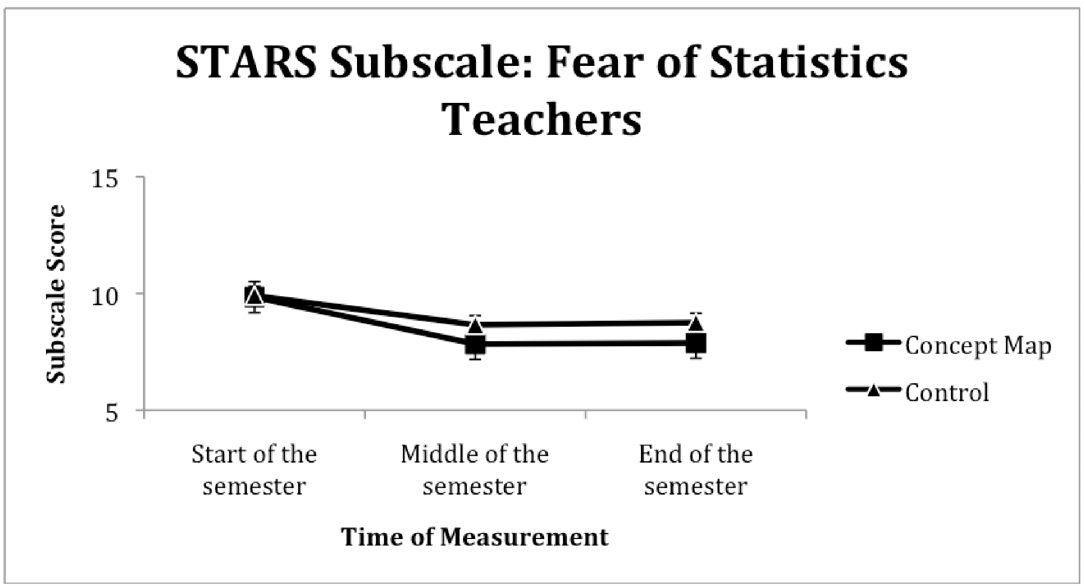

Figure 8. Mean Fear of Statistcs Teachers anxiety scores for the concept map and control groups. *Note*. Error bars represent +/-1SE.

Statistics Exam Performance Findings

Overall exam performance. For exam 1, the concept map group (M = 41.52, SD = 5.64, n = 49) and the control group (M = 41.55, SD = 4.93, n = 52) demonstrated equal levels of performance. For exam 2, the concept map group (M = 39.63, SD = 8.32, n = 49) produced practically equal scores as the control group (M = 39.37, SD = 8.29, n = 52). For exam 3, the concept map group (M = 38.71, SD = 7.98, n = 47) again produced practically equal scores as the control group (M = 38.46, SD = 7.06, n = 52). The same pattern continued for exam 4, with the concept map group (M = 38.90, SD = 8.02, n = 47) scoring equally well as the control group (M = 38.76, SD = 6.53, n = 51). Figure 9 shows the patterns of overall exam scores over the semester for each condition.

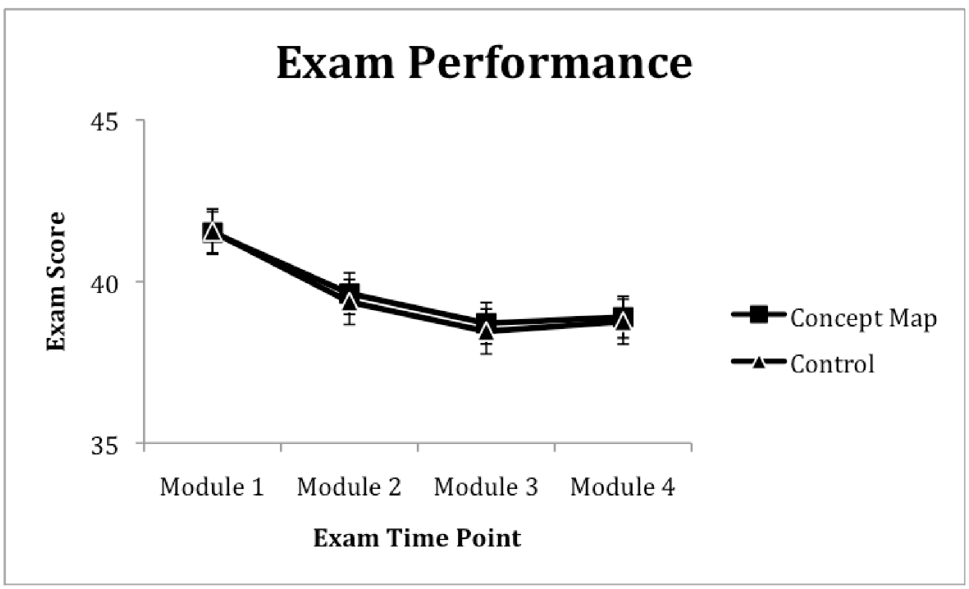

Figure 9. Mean exam performance for the concept map and control groups.
Note. Error bars represent +/-1SE.

A mixed analysis of variance was used to analyze the overall (conceptual and computational scores combined) exam data, with time as a repeated measures factor and the experimental conditions as a between-subjects factor. A significant main effect of time was found, $F(3, 285) = 7.24$, $p < .001$, $\eta^2 = .070$, showing that academic performance changed for both the treatment and control group from the beginning to the end of the semester. However, there was no significant main effect of group, $F(1, 95) = 0.05$, $p = .811$, $\eta^2 = .00001$, showing that concept mapping did not have a significant effect on academic performance for the concept map group. There was also no significant interaction identified between the two groups on overall performance, $F(3, 285) = 0.07$, $p = .972$, $\eta^2 = .0007$.

Exam performance: Conceptual questions. For exam 1, the concept map group ($M = 18.76$, $SD = 3.65$, $n = 49$) and the control group ($M = 18.60$, $SD = 3.47$, $n = 52$) demonstrated practically equal levels of performance. For exam 2, the concept map group ($M = 19.00$, $SD = 3.94$, $n = 49$) again produced practically equal scores as the control group ($M = 18.50$, $SD = 4.46$, $n = 52$). For exam 3, the concept map group ($M = 17.49$, $SD = 3.94$, $n = 47$) produced slightly higher scores than the control group ($M = 17.17$, $SD = 3.75$, $n = 52$). For exam 4, the concept map group ($M = 16.87$, $SD = 4.68$, $n = 47$) produced an overall average that was a point higher than that of the control group ($M = 15.76$, $SD = 4.69$, $n = 51$). Figure 10 shows the patterns of exam conceptual scores over the semester for each condition.

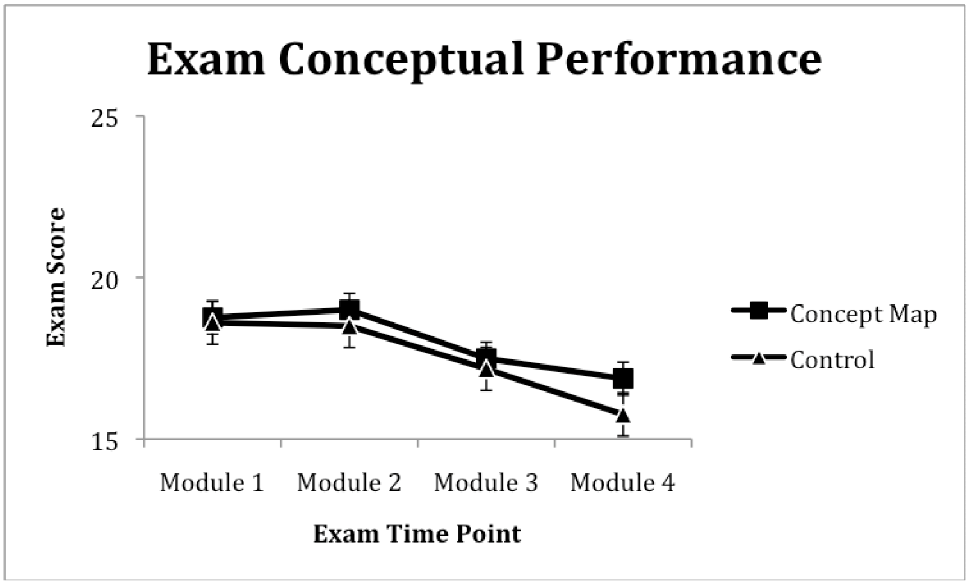

Figure 10. Mean exam conceptual performance for the concept map and control groups. *Note.* Error bars represent +/-1SE.

A mixed analysis of variance was used to analyze the conceptual exam data, with time as a repeated measures factor and the experimental conditions as a between-subjects factor. A significant main effect of time was found for this measure, $F(3, 285) = 17.98$, $p < .001$, $\eta^2 = .158$, showing that conceptual performance decreased for both the concept map and control group from the beginning to the end of the semester. However, no main effect of group was found between the treatment and control groups on conceptual performance, $F(1, 95) = 0.62$, $p = .432$, $\eta^2 = .0002$, showing that concept mapping did not have a significant effect on conceptual performance for the treatment group. There was also no significant interaction found between the two groups on conceptual performance, $F(3, 285) = 0.73$, $p = .534$, $\eta^2 = .006$.

Exam performance: Computational questions. For exam 1, the concept map group ($M = 22.77$, $SD = 2.99$, $n = 49$) demonstrated slightly less computational understanding than the control group (*M* = 22.95, *SD* = 2.72, *n* = 52). For exam 2, the concept map group (*M* = 20.63, *SD* = 5.38, *n* = 49) again produced lower scores than the control group (*M* = 20.87, *SD* = 4.64, *n* = 52). For exam 3, the concept map group (*M* = 21.22, *SD* = 4.81, *n* = 47) produced approximately equal scores as the control group (*M* = 21.29, *SD* = 4.05, *n* = 52). For exam 4, the concept map group (*M* = 22.03, *SD* = 4.64, *n* = 47) overall score was a point higher than that of the control group (*M* = 23.00, *SD* = 2.96, *n* = 51). Figure 11 shows the patterns of exam computational scores over the semester for each condition.

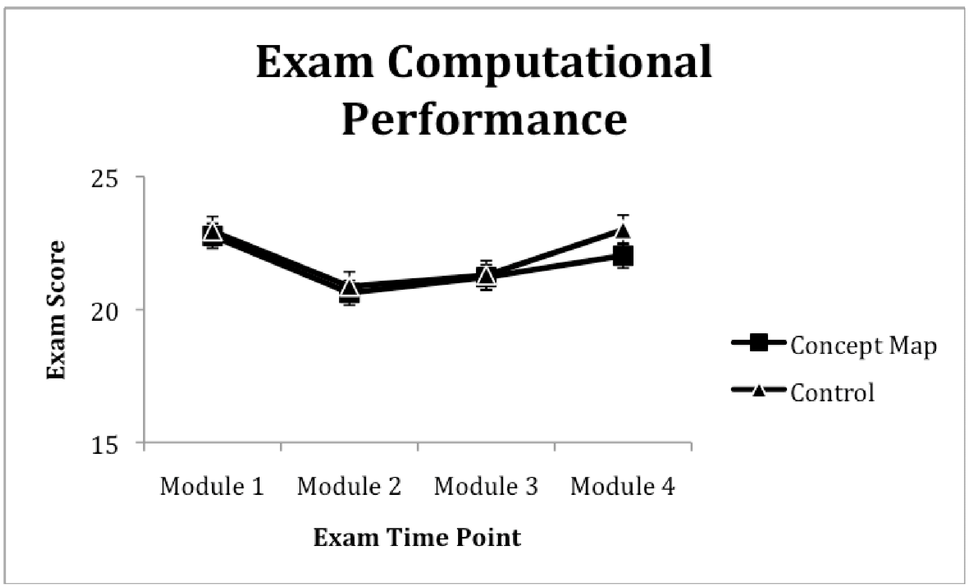

Figure 11. Mean exam computational performance for the concept map and control groups. *Note.* Error bars represent +/-1SE.

A mixed analysis of variance was used to analyze the computational exam data, with time as a repeated measures factor and the experimental conditions as a between-subjects factor. A significant main effect of time was found for this measure, $F(3, 285) = 9.70$, $p < .001$, $\eta^2 = .092$, showing that computational performance initially decreased, then slightly increased for both the concept map and control groups from the beginning to the end of the semester. However, no main effect of group was found between the treatment and control groups on computational performance, $F(1, 95) = 0.16$, $p = .685$, $\eta^2 = .00003$, showing that concept mapping did not have a significant effect on computational performance for the treatment group. There were also no significant interaction found between the two groups on computational performance, $F(3, 285) = 0.28$, $p = .834$, $\eta^2 = .002$.

Concept Mapping Proficiency

Concept map assessment reliability. The proficiency of a participant's concept mapping was assessed using two approaches, namely, the quantitative map scoring and the qualitative concept map rubric (which were combined to form a single concept map score). In order to assess the reliability of these measures, Pearson correlations were conducted in order to compare the concept map quantitative scores and the concept map qualitative (rubric) scores for each of the four sets of concept maps. The correlation for the third concept map on estimation approached significance with a *p* value of .055. The lack of significance between the quantitative and rubric scores for the estimation map may be due to small sample size, as only 25 maps were included in the analysis, opposed to between 30 and 37 maps being included in the analyses of the other three concept map quantitative and rubric scores. All of the three remaining correlations were significant. These correlations are listed in Table 1.

Table 1

Instrument and Inter-Rater Reliability Correlations

Concept Map Set	Assessment Instruments	Inter-Rater Reliability
1. Hypothesis Testing	.58***	.98***
2. *t* statistic	.47**	.97***
3. Estimation	.39	.98***
4. ANOVA	.44*	.99***

Note. Two-tailed significance tests were used.
* $p < .05$, ** $p < .01$, *** $p < .001$

To examine the inter-rater reliability of the concept map scoring method used in this experiment, an independent rater scored 10 maps from each of the four original concept map assignment pools of participant maps. The 10 maps from each pool were randomly chosen (http://www.random.org/). The independent rater was taught to score the maps using the quantitative and rubric techniques and then to combine those scores into a single concept map score. Pearson correlations between the experimenter and independent rater concept map scores were computed. These correlations are also listed in Table 1. All four of the inter-rate correlations were significant, providing evidence for the reliability of the concept maps scoring techniques used in this experiment.

Proficient and non-proficient ratings. In order to categorize the treatment participants into concept map usage groups (proficient users and non-proficient users), a median split was conducted for each of the four original map assignment pools. The median score for the hypothesis testing map was 35, so any participant creating a map with a score of 35 or higher was classified as proficient on this map topic and any participant creating a map with a score lower than 35 was classified as non-proficient on this map topic. For the hypothesis testing map, the proficient group (M = 47.83, SD = 13.37, n = 18) represented a range of scores between 35 and 81, whereas the non-proficient group (M = 26.09, SD = 5.66, n = 17) represented a range of scores between 15 and 34. The median score for the t statistic map was 35. For the t statistic map, the proficient group (M = 43.95, SD = 6.46, n = 19) represented a range of scores between 35 and 58.5, where the non-proficient group (M = 24.67, SD = 6.21, n = 18) represented a range of scores between 13 and 32. The median score for the estimation map was 38.5. For the estimation map, the proficient group (M = 43.42, SD = 3.45, n = 13) represented a range of scores between 38.5 and 50, whereas the non-proficient group (M = 24.75, SD = 6.22, n = 12) represented a range of scores between 17 and 37.5. The median score for the ANOVA map was 35.5. For the ANOVA map, the proficient group (M = 46.84, SD = 11.89, n = 16) represented a range of scores between 35.5 and 71.5, where the non-proficient group (M = 26.10, SD = 6.96, n = 14) represented a range of scores between 16 and 34.

Proficient and non-proficient exam performance. Independent-samples t-tests were used to analyze the concept map usage data. The proficient and non-proficient ratings from the map on the t statistic were to test for differences in performance on exam 3, whereas the proficient and non-proficient ratings from the map on ANOVA were used to test for differences in performance on exam 4. The ratings from these two maps were used because their creation occurred closest in time to the given exam and are therefore the most indicative map of the participants' knowledge regarding the given exam. This ensured that the most current measure of concept map proficiency would be used, so that anyone who was non-proficient on a prior map had the opportunity to improve. Exam 3 covered hypothesis testing, the *t* statistic, and the different types of *t*-tests. Exam 4 covered estimation, confidence intervals, and ANOVA. Each test contained conceptual and computational questions.

For exam 3, the proficient group (*M* = 41.97, *SD* = 4.98, *n* = 18) produced about a 4-point higher overall score than the non-proficient group (*M* = 38.03, *SD* = 9.13, *n* = 18). No significant differences were found among the proficient and non-proficient concept map users on exam 3 conceptual score, $t(34) = 0.70$, $p = .486$, $d = 0.23$, or total score, $t(34) = 1.61$, $p = .117$, $d = 0.53$. However, for the computational section of exam 3, the proficient group (*M* = 23.58, *SD* = 2.05, *n* = 18) produced a 3-point higher score than the non-proficient group (*M* = 20.58, *SD* = 5.07, *n* = 18). A significant difference in computational score on exam 3 (see Figure 12) was revealed among the proficient and non-proficient concept map users, $t(34) = 2.33$, $p = .026$, $d = 0.77$.

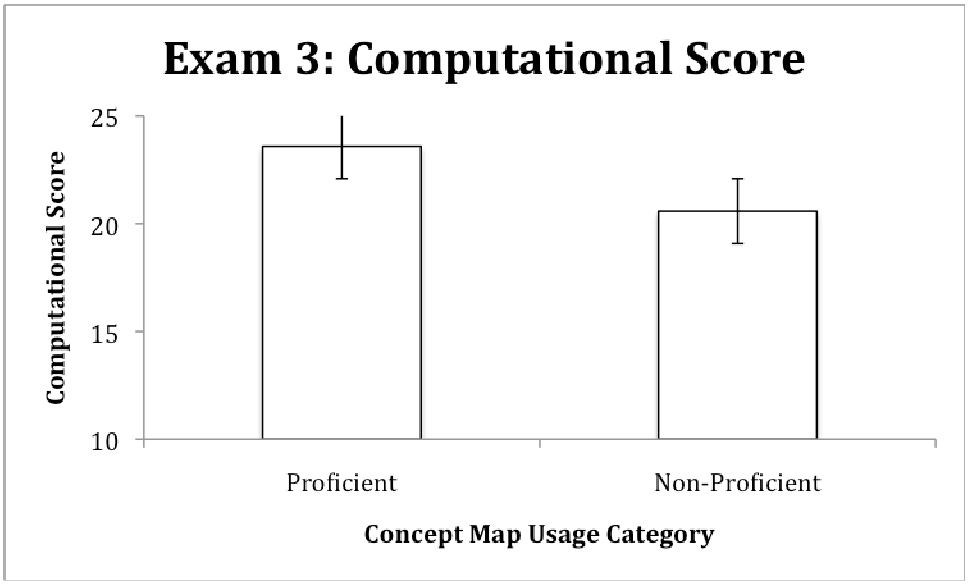

Figure 12. Exam 3 mean computational score for the *t* statistic concept map proficient and non-proficient users. *Note.* Error bars represent +/-1SE.

For exam 4, the proficient group (*M* = 43.09, *SD* = 4.47, *n* = 16) again produced about a 5-point higher overall score that the non-proficient group (*M* = 38.25, *SD* = 7.50, *n* = 14), yielding a significant difference between the proficient and non-proficient concept map users, $t(28) = 2.18$, $p = .038$, $d = 0.78$ (see Figure 13). No significant differences were found among proficient and non-proficient users on exam 4 computational score, $t(28) = 1.49$, $p = .146$, $d = 0.45$, or conceptual score, $t(28) = 1.92$, $p = .065$, $d = 0.70$.

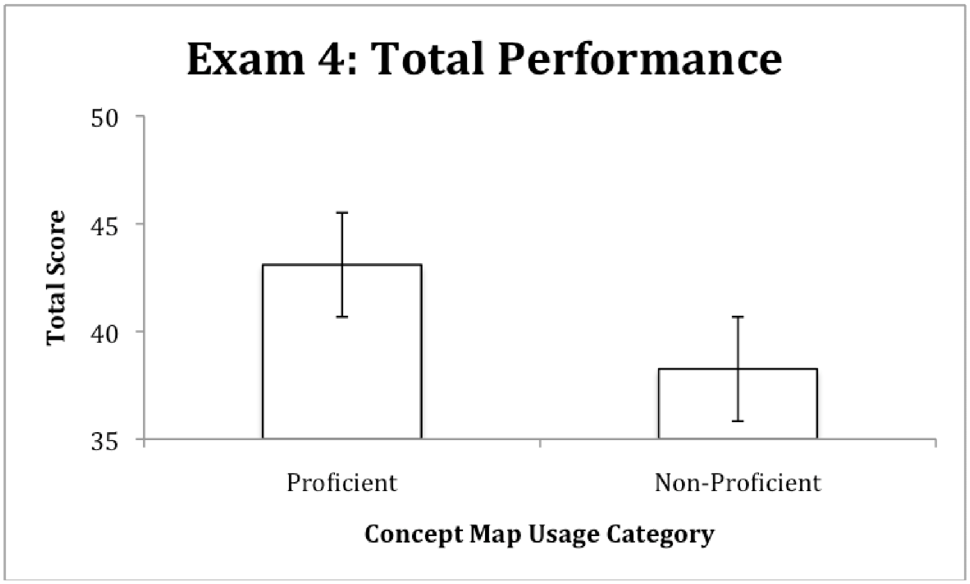

Figure 13. Exam 4 mean performance for the ANOVA concept map proficient and non-proficient users. *Note.* Error bars represent +/-1SE.

Proficient concept map users and control group performance. Independent-samples *t*-tests were used to compare the proficient concept map users to the control group participants. The proficient ratings from the map on the *t* statistic were used to determine the group to be compared to the control group participants on exam 3, whereas the proficient ratings from the map on ANOVA were used to determine the group to be compared to the control group participants on exam 4. The ratings from these two maps were used because their creation occurred closest in time to the given exam and are therefore the most indicative map of the participants' knowledge regarding the given exam. This ensured that the most current measure of concept map proficiency would be used, so that anyone who was non-proficient on a prior map had the opportunity to improve. Exam 3 covered hypothesis testing, the *t* statistic, and the different types of *t*-

tests. Exam 4 covered estimation, confidence intervals, and ANOVA. Each test contained conceptual and computational questions.

For exam 3, the proficient group (*M* = 23.58, *SD* = 2.05, *n* = 18) produced over a 2-point higher computational score than the control group (*M* = 21.29, *SD* = 4.05, *n* = 52). A significant difference was found between the proficient concept map users and the control participants on exam 3 computational score, *t*(68) = 2.29, *p* = .025, *d* = 0.71 (see Figure 14). No significant differences were found among the proficient concept map users and the control participants on exam 3 conceptual score, *t*(68) = 1.22, *p* = .225, *d* = 0.34, or total score, *t*(68) = 1.94, *p* = .056, *d* = 0.57.

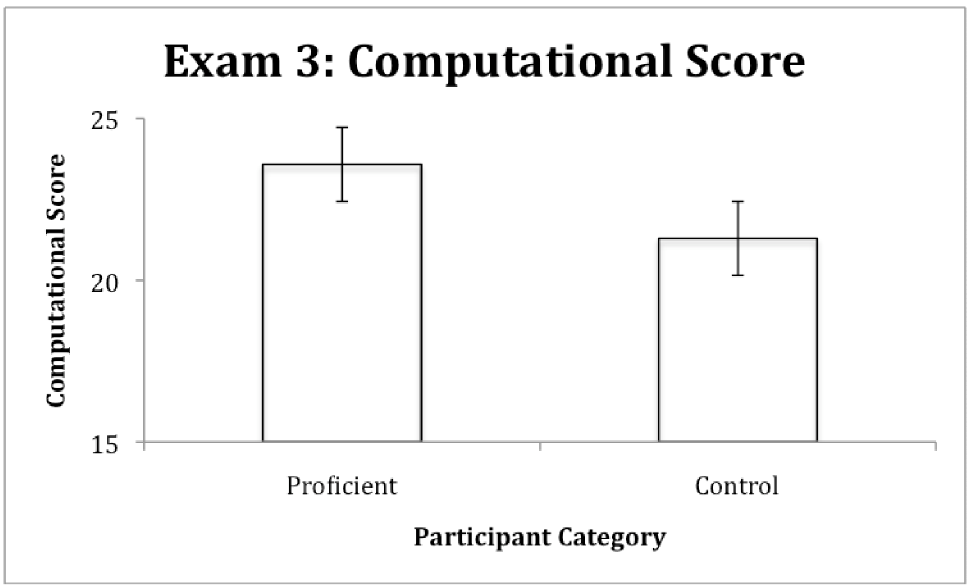

Figure 14. Exam 3 mean computational score for the *t* statistic proficient concept map users and the control participants. *Note.* Error bars represent +/- 1SE.

For exam 4, the proficient group (*M* = 19.06, *SD* = 3.79, *n* = 16) produced over a 3-point higher conceptual score than the control group (*M* = 15.76, *SD* = 4.69, *n* = 51). A significant difference was found between the proficient concept map users and the control participants on exam 4 conceptual score, $t(65) = 2.56$, $p = .013$, $d = 0.77$ (see Figure 15).

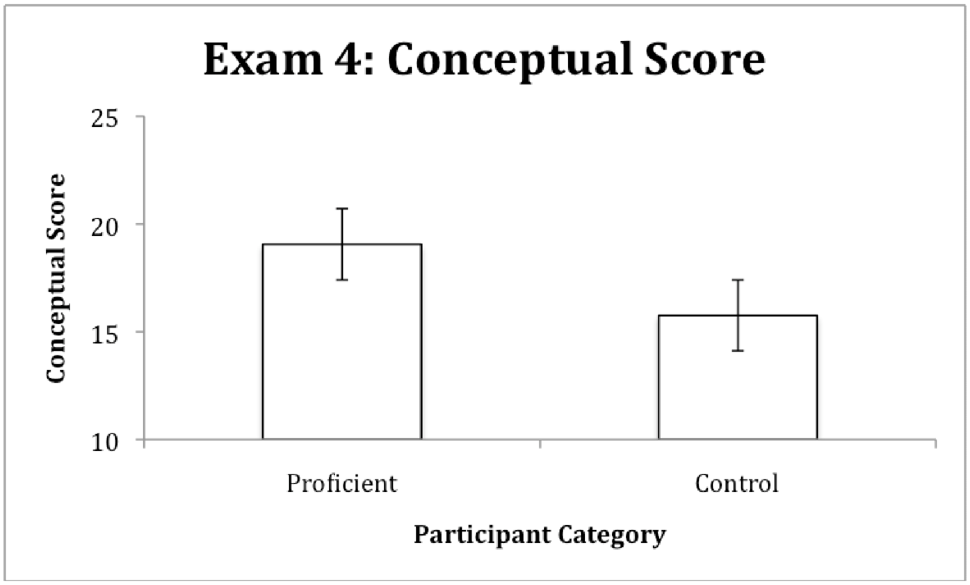

Figure 15. Exam 4 mean conceptual score for the ANOVA proficient concept map users and the control participants. *Note.* Error bars represent +/-1SE.

For exam 4 total score, the proficient group ($M = 43.09$, $SD = 4.47$, $n = 16$) produced over a 4-point higher score than the control group ($M = 38.76$, $SD = 6.53$, $n = 51$). A significant difference was found between the proficient concept map users and the control participants on exam 4 total score, $t(65) = 2.47$, $p = .016$, $d = 0.77$ (see Figure 16). No significant difference was found between the proficient concept map users and the control participants on exam 4 computational score, $t(65) = 1.34$, $p = .184$, $d = 0.44$.

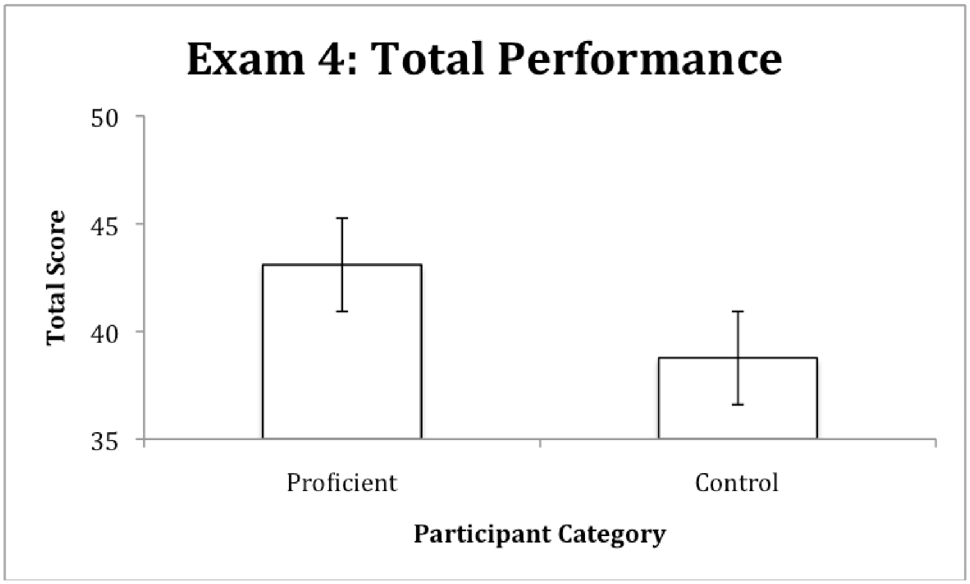

Figure 16. Exam 4 mean performance for the ANOVA proficient concept map users and the control participants. *Note.* Error bars represent +/-1SE.

Concept Map Usage Questionnaire Results

End of training questionnaire summary. In total, 30 participants form the concept map group completed the end of training concept map usage questionnaire. Of the 14 questions on this inventory (See Appendix C), 12 were answered using a 5-point Likert-type agreement scale anchored with a 1 (*Strongly Disagree*) and a 5 (*Strongly Agree*). The descriptive statistics for the group responses to these statements are presented in Table 2. Of the remaining questions on this survey, one asked which map the participant preferred to use and one asked if the participant had prior experience using concept maps in a class. Of the three types of maps taught to the class, most students preferred using a chain map (36.5%, n = 11), followed closely by a net map (33.5%, n = 10), and coming next was a spoke map (20%, n = 6). A small portion of the students noted that they preferred using a *Venn diagram* (10%, n = 3) more than any of the three maps taught to the group. A Venn diagram is a comparison tool that allows for the visualization of relationships between two topics by utilizing two overlapping circles (Venn, 1881). This type of diagram was used with the concept map class, but not nearly as often as the three types of concept maps. Of the respondents in the concept map class, the majority had prior experience with concept maps in high school or college (57%, n = 17), and the remainder of the participants had no prior concept map experience (43%, n = 13).

Table 2

Descriptive Statistics for Agreement Scale Statements from the End of Training Concept Map Usage Questionnaire

Statements	*M*	*SD*
1. I understand what a concept map is.	4.30	1.12
2. I understand the three types of concept maps discussed in class.	3.87	0.97
3. I understand when to use each type of concept map discussed in class.	3.00	0.87
4. The concept map homework assignments are useful for learning the material covered in my statistics course.	3.87	1.01
5. The concept map homework assignments have been stressful for me.	2.47	1.20
6. The concept map in-class lessons are useful for learning the material covered in my statistics course.	3.73	0.98
7. The concept map in-class activities are useful for learning the material covered in my statistics course.	3.63	1.00
8. The "Concept Map Review" document was useful for clarifying the question(s) I had about concept mapping.	3.83	0.87
9. I include concept maps in the notes I take for my statistics course.	2.40	1.10
10. I use concept maps, outside of class, to study the material covered in my current statistics course.	2.53	1.20
11. I plan on using concept-mapping techniques to study statistics over the rest of the semester.	3.03	1.07
12. I plan on using concept-mapping techniques to study for my other courses over the rest of the semester.	2.67	1.24

End of semester questionnaire summary. In total, 34 participants form the concept map group completed the end of semester concept map usage questionnaire. Of the 11 questions on this inventory (See Appendix D), 7 were answered using a 5-point Likert-type agreement scale anchored with a 1 (*Strongly Disagree*) and a 5 (*Strongly Agree*). The descriptive statistics for the group responses to these statements are presented in Table 3. Of the remaining questions on this survey, the participants were again asked which map they preferred to use and if they had prior experience using concept maps. For this inventory, most students noted that they preferred using a net map (32%, n = 11), followed by a spoke map (26%, n = 9), coming next was a chain map (24%, n = 8), and finally a portion of the sample reported having no preference (18%, n = 6). This pattern differed from the end of training questionnaire, showing a more balanced distribution of preferred map usage among the different types of concept maps. The majority of the concept map group respondents again reported having prior experience with concept maps in high school or college (65%, n = 22), and the remainder of the participants had no prior concept map experience (32%, n = 11) or did not provide and answer (3%, n = 1). The last two questions on this inventory were dichotomous items requiring a yes or no answer to indicate if a participant included concept maps in their statistics notes and if a participant used concept maps outside of class to study statistics. The majority of the respondents reported that they did not use concept maps in their statistics notes (65%, n = 22), and the remaining students indicated that they did include concept maps in their statistics notes (35%, n = 12). The majority of the respondents also reported that they did not use concept maps to study statistics (71%, n = 24), and the remaining students indicated that they did use concept maps to study statistics (29%, n = 10).

Table 3

Descriptive Statistics for Agreement Scale Statements from the End of Semester Concept Map Usage Questionnaire

Statements	M	SD
1. The concept map homework assignments were useful for learning the material covered in this statistics course.	3.85	0.86
2. The concept map homework assignments were stressful for me.	2.06	0.89
3. I plan on using concept-mapping techniques to study for any future statistics course that I may take.	3.24	0.89
4. I plan on using concept-mapping techniques to study for other future courses, besides statistics courses, that I may take.	3.29	0.91
5. I feel that using concept-mapping strategies was useful For increasing my theoretical understanding of statistics.	3.65	0.92
6. I feel that using concept-mapping strategies was useful for improving my academic performance in this statistics course.	3.50	0.90
7. I feel that using concept-mapping strategies was useful for decreasing my anxiety towards statistics.	3.35	0.98

Discussion

Study Summary

The statistics anxiety of the concept map group decreased more than that of the control group over the course of the semester, but none of the group differences on anxiety were found to be statistically significant. The anxiety prediction for this study was that the use of concept mapping would significantly decrease the overall statistics anxiety of students in the concept map group and that these students would have less statistics anxiety over the semester than the students in the control group. The results do not support this hypothesis.

The academic performance of the concept map group remained relatively stable and similar to the control group throughout the course of the semester. None of the small group differences on academic performance were found to be statistically significant. However, for exam 3, a significant difference was found between the proficient concept map users and the control participants on computational score. For exam 4, a significant difference was found between the proficient concept map users and the control participants on conceptual score and total score. These performance patterns suggest that the use of concept mapping provided the proficient concept map users with academic advantages over the control group participants. The performance prediction for this study was that the use of concept mapping would significantly improve the academic performance of students in the concept map group and that these students would improve more academically over the semester than the students in the control group. The results support this hypothesis.

Strengths and Limitations

Significant results to consider. A significant difference was found between the concept map group and the control group on the STARS subscale of Interpretation Anxiety. This type of statistics anxiety is related to trying to understand another person's interpretation of statistics as well as having to make one's own interpretations of statistics. Interpretation anxiety appears to be related to one's conceptual understanding of statistics, so the use of concept mapping may have made those in the concept map group feel less anxious about interpreting statistics and more confident about their conceptual understanding of statistics. However, this speculative logic does not explain why any newfound participant confidence did not translate to significantly higher conceptual performance on their exams. According to the logic of processing efficiency theory (e.g., Eysenck & Calvo, 1992), such an improvement in conceptual performance would be expected, as working memory space should have been freed up by having less worry over one's interpretation of statistics.

It is worthy to note that the only significant difference in performance found between members of the concept map group was on computational performance on the third exam. According to processing efficiency theory (e.g., Eysenck & Calvo, 1992), impaired performance is more consistent during stressful conditions, so the significant difference between the proficient concept map users and the non-proficient users in a test situation implies that making better maps lead to better computational performance. This significant difference may be a function of the topic for the map they created before the test. They mapped out their thoughts on the topic of the *t* statistic, showing that the proficient users understood more about how to compute this statistic than did the non-proficient users. This result mirrors the assertion that creating a personal concept map supports the effective organization of knowledge and allows students to solve structured problems more efficiently than if they were just given a concept map made by an teacher (Lee & Nelson, 2005). Therefore, by creating a more robust, individual concept maps, including how to compute the *t* statistic, it appears the proficient user's computational organization translated into less calculation errors and higher computational exam scores than the non-proficient users on exam 3.

A significant difference on exam 3 computational score was also found between the proficient concept map users and the control group. In addition, significant differences were found between the proficient concept map users and the control group on exam 4 conceptual score and total score. These exam 4 results differ from the between-group findings comparing the entire concept map group (proficient and non-proficient users) to the control group, which did not yield any significant performance results. The lack of significance in the between-group performance analyses may be explained by the presence of the non-proficient concept map users. This group may have washed out any significant effect between the proficient concept map users and the control group.

Validity and reliability. According to Lavigne (2005), the majority of researchers have used a quantitative analysis of concept map structure to assign scores to the maps they study. It has also been recommended that a qualitative analysis of concept map structure be used rather than a quantitative analysis because it can provide more analytic value (Kinchin, Hay, & Adams, 2000). In order to provide concurrent validity to this study, it was decided to use both the more established method of quantitative analysis of map structure and the more diagnostic method of qualitative analysis of map structure.

For our quantitative analysis, we counted the number of nodes, links, branches, pictures, colors, statistical formulas, and awarded a point for correct concept map structure. The qualitative analysis was the scoring rubric (see Appendix E) developed by the experimenter through examining other concept map rubrics, identifying useful segments from those rubrics, and finally synthesizing ideas from those segments into a new rubric. The structure of the rubric included sections covering ideas addressed in each of the other rubrics that were examined, ensuring face validity and content validity, while leaving out ideas that were not widely addressed, in order to strengthen the content validity of the measure. Concurrent validity was shown through significant correlations between the quantitative and qualitative analysis of map structure on three of the four sets of original maps created by the concept map group (see Table 1). The set of maps covering the topic of estimation did not yield a significant correlation. However, with a p value of .055, the correlation was approaching significance for this set, with significance most likely prevented by small sample size.

Providing a measure of concurrent validity also allows for a discussion of the convergent validity of the quantitative and qualitative analyses of map structure used in this experiment. The two constructs used to assess the concept maps created by the concept map group were correlated with each other despite small sample sizes, showing that the two different methods did indeed measure the same construct. The establishment of concurrent and convergent validity reinforces the construct validity of the assessment methods used for this experiment.

In using both a quantitative scoring method and a qualitative scoring method, then combining each of these scores to form a single concept map score, Pearson correlations were conducted in order to compare the reliability of these measures. As previously mentioned, three of the four sets of original maps created by the treatment group yielded significant correlations, showing reliability between the two measures. Only the estimation map failed to yield a significant correlation, but this is believed to be due to small sample size.

An independent rater was recruited to score ten maps from each of the four original concept map assignment pools of participant maps, allowing for the examination of the inter-rater reliability of the scoring methods used in this experiment. Pearson correlations between the experimenter and independent rater concept map scores were conducted (see Table 1), yielding significant correlations and providing further evidence for the reliability of the concept maps scoring techniques used in this experiment. Finally, Cronbach's alpha (α) was used to estimate the reliability of the STARS scale items, yielding acceptable estimates of internal consistency (Nunnally, 1994) for each of the STARS subscales. These estimates coincide with past studies showing the STARS as a reliable measure of statistics anxiety (Mji & Onwuegbuzie, 2004; Onwuegbuzie, 1999). In showing the reliability of the measures used in this study, the argument for the validity of the experiment is strengthened further.

Small effect sizes insufficient statistical power. One constant throughout each analysis conducted was the presence of small effect sizes of concept mapping on the concept map group. Even the largest of the differences maintained between the concept map group and the control group only accounted for less than four percent of a decrease in feelings of anxiety. A similar pattern was present between the concept map and control groups for academic performance, as less than a two percent increase in performance was the achievement ceiling. When looking for a medium effect with an estimated power of .80 at a p value of .05, the recommended amount of participants for the study was 128 (Cohen, 1992). In total, only 101 participants were attained for the experiment, missing the required number for sufficient statistical power by 27 participants.

Implications

Potential population oversight. The results of this study may reflect differences between the general undergraduate student population and specific populations of undergraduate students (e.g. math or business majors). In this study, the use of concept mapping did not significantly reduce the anxiety of the participants in the concept map group, which was made up of a variety of majors. Although it was our intention to investigate if subgroups of students, stratified by major, had their anxiety significantly reduced by the use of concept mapping, we were not able to conduct such an investigation due to problematic data. Past studies have shown concept mapping to have a positive effect on students at the graduate level, including medical students (Torre et al., 2007) and social science students (Pan & Tang, 2004). In the future, it may be important to consider if the general constitution of the study population concealed any subpopulations of undergraduates that were more greatly affected by the use of concept mapping.

Conceptual vs. computational advantages. From the outset of this experiment, it was believed that the use of concept mapping would have more of an impact on conceptual exam performance than on computational exam performance. This belief was based on prior research showing conceptual models to improve recall of conceptual information (Mayer, 1989) and the use of metacognitive strategies to lead to improved academic performance (Metallidou & Viachou, 2007). In addition, processing efficiency theory states that successful processing activities can increase available working memory capacity and lead to improved performance (e.g. Eysenck & Calvo, 1992). Concept mapping has been shown to be a successful processing activity for college students (Pan & Tang, 2004; Torre et al., 2007), and therefore it was believed to be a possible strategy for improving working memory in college statistics students.

The conceptual and computational performance of proficient and non-proficient concept map users was tracked for exams 3 and 4. The only significant difference between these groups was on the exam 3 computational, where the proficient users performed three points better than the non-proficient users. In addition, a significant difference was found between the proficient concept map users and the control participants on exam 3 computational score. For exam 4, a significant difference was found between the proficient concept map users and the control participants on conceptual score and total score. These performance patterns suggest that the use of concept mapping provided the proficient concept map users with computational and conceptual academic advantages over the control group participants.

Modification of the Current Study

It may be worthwhile to replicate the current study with some specific modifications in order to strengthen the experimental design and show the original anxiety hypothesis to be valid. First, any replication should include more participants, at least 128 in order to meet the recommended amount to reach sufficient statistical power. That way there will be no question if null results are found again.

Improvements in concept map training. Other issues to be addressed when modifying the current study are the length and the strength of the concept map training portion of this study. A more concise and intense concept map training regime may produce a stronger treatment and larger effect sizes then those in the current study. It may have been that the concept map training for the current study concentrated on understanding concepts maps at the expense of taking away valuable time that could have been used on learning more about statistics. Condensed, precise training sessions would allow participants to spend more time applying concept map techniques to statistics, giving the concept map training more of a chance to work in improving the students conceptual understanding of statistics. The participants may have shown a greater amount of reduced statistics anxiety and improved academic performance if they learned the minimum amount necessary to create their own maps and then spent the majority of their time honing their concept map skills by creating maps about statistics topics.

The concept map training for the current experiment also may have lasted too long. The participants were still learning about concept maps until the midpoint of the semester, and the original concept map assignments did not begin until after the second exam. The graph of exam conceptual performance clearly shows the concept map group and the control group were practically even as far as score on exam 3, but the concept map group clearly performed better than the control group on exam 4. This improvement may have been due to the creation of personal maps that the concept map class had begun after exam 2. They may have performed even with the control group on exam 3 because they were still learning how to best create their own maps, but by exam 4 they were done making adjustments and were performing better than the control group. If the training were to last only a few weeks and then the participants began creating their own maps, one might predict a pattern of even performance with the control group on exam 1 but steady improvement over the control group on the next three exams. It would also be interesting to see the pattern that would ensue with exam computational performance with the outlined changes made. The graph of exam computational performance shows the concept map group and the control group were practically even as far as exam score on exam 3, but the control group clearly performed better than the concept map group on exam 4. This pattern may be a product of chance, and having more time to create personal maps might lead to higher computational performance for the concept map group.

Spending less time practicing and spending more time creating personal maps may also help to reduce statistics anxiety because less time would be spent trying to understand concept maps and more would be spend trying to understand statistics. The belief is that the advantages of concept mapping, such as making misconceptions easier to identify (McClure et al., 1999) and providing the articulation of more relationships between statistical concepts (Lavigne, 2005), will lead to a deeper conceptual understanding of statistics, which will lead to less statistics anxiety and in turn create more confidence in one's statistics abilities. The significant differences in Interpretation Anxiety between the concept map group and the control group illustrate this point, showing that the concept map group felt more confident in its understanding of statistics and its ability to explain statistics due to concept mapping. An increase in the amount of time dedicated to creating concept maps is recommended for any replication attempt, but the key is to make the suggested modifications in order to maintain a proper balance between learning concept mapping and learning statistics.

Suggestions for Future Research

Investigating specific student groups. Once the discussed improvements have been made to the experiment design, it may be beneficial to study specific groups of undergraduate students to see if concept maps are more effective for any particular group. It has been found that statistics-anxious students avoid statistics coursework and college majors that require statistics (Onwuegbuzie & Wilson, 2003), so one might hypothesize that math or business majors who have chosen subject areas that will involve more math or statistics classes than other majors may be more willing to utilize concept mapping as a strategy because they are not as statistics-anxious. The motivation to try concept mapping may be greater for students who are more secure about their math or statistics abilities than most in the general population.

Investigating conceptual and computational learning advantages. Proficient concept map users performed significantly better on the computational section of exam 3 than the non-proficient concept map users. Proficiency status in this situation was based on the *t* statistic concept map, so it may be that the participants created maps that focused on how to compute this statistic that facilitated improved computational performance. It is also possible that the participants performed significantly better on the computational section of the exam 3 because the typical student has a limited understanding of mathematics mostly related to computational skills, with little to no relation to conceptual understanding (Perry, 2004). Therefore, the participants may have performed better on the computational section because their conceptual understanding was not as developed as their computational understanding of statistics. Creating concept map assignments with more specific instructions, geared toward computational or conceptual understanding, may help facilitate greater overall academic improvements.

In order to understand the conceptual and computational learning advantages that may be gained from using concept maps, future research can include the use of map directions designed specifically to provide one learning advantage over the other. For instance, participants in one group could create maps outlining the steps in calculating an ANOVA and participants in another group could create maps outlining the conceptual underpinnings of ANOVA. A third group could even be included that creates a map with both conceptual and computational information. It would be interesting to see if the groups differ significantly in the conceptual and computational scores from an exam covering ANOVA. It may be that more directed mapping instructions produce distinct advantages that open-ended mapping instructions, like the ones used in this study, do not.

Working memory assessment. In future research, it may be necessary to measure and track certain cognitive functions that previous research has shown to be related to anxiety and academic performance. As discussed in this document, working memory is impeded by feelings of worry (Eysenck & Calvo, 1992), and math-anxious students have been found to encounter working memory difficulties (Ashcraft & Moore, 2009). Eysenck and Calvo (1992) stated that when working memory is hindered by anxiety it has negative effects on performance, and this type of performance decline due to working memory interference has been found to worsen for math students as the material becomes more abstract and a heavier load is placed on working memory (LeFevre, DeStefano, Coleman, & Shanahan, 2005). In studying statistics anxiety, working memory should also be assessed and then the two measures can be correlated to see if they are related. If working memory function is related to statistics anxiety, then it could be included as a covariate in any future analysis of statistics anxiety data. Such action would produce a more statistically powerful study of statistics anxiety.

Metacognition assessment. Another cognitive function that may be related to statistics anxiety is metacognition, which is defined as awareness of one's personal thinking processes and one's ability to control his or her thinking processes (Flavell, 1979). Metacognitive strategies have been found to be predictors of college student math anxiety (Kesici & Erdogn, 2009). Specifically, students who do not consider metacognitive strategies as important have a decreased probability of academic success in math courses. Other findings show that the use of metacognitive strategies, such as concept mapping, leads to better performance in college students (Metallidou & Viachou, 2007). Concept mapping is a metacognitive skill because it facilitates the process of thinking about one's thinking. Metacognitive skills are difficult for college students to master (Mattick & Knight, 2007), so it is recommended that the measurement of these abilities is coupled with more intense training methods as were described above. More intense training would involve detailed feedback for each participant about the content of their map, including inaccuracies in interpretation and affirmation of valid lines of thought. Being that this type of feedback was lacking from the current study and individual metacognitive ability, the ranges of differences in metacognitive abilities among the participants may have contributed to the lack of findings. By not separating the participants with more metacognitive skill and combining them with the participants with less metacognitive skill in the analysis, it would be difficult to see the advantages of having honed metacognitive skills in a statistics class. In studying statistics anxiety, metacognition should also be assessed and then the two measures can be correlated with one another to see if they are related. Then if metacognitive function is related to statistics anxiety, it could be included as a covariate in any analysis of future statistics anxiety data, which would produce a more statistically powerful study of statistics anxiety.

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Appendix A

Concept Map Extra Credit Assignment #5: Probability Item List

Node Instructions: Match each of the terms/definitions below with the node number they belong to on the Probability Map Worksheet.

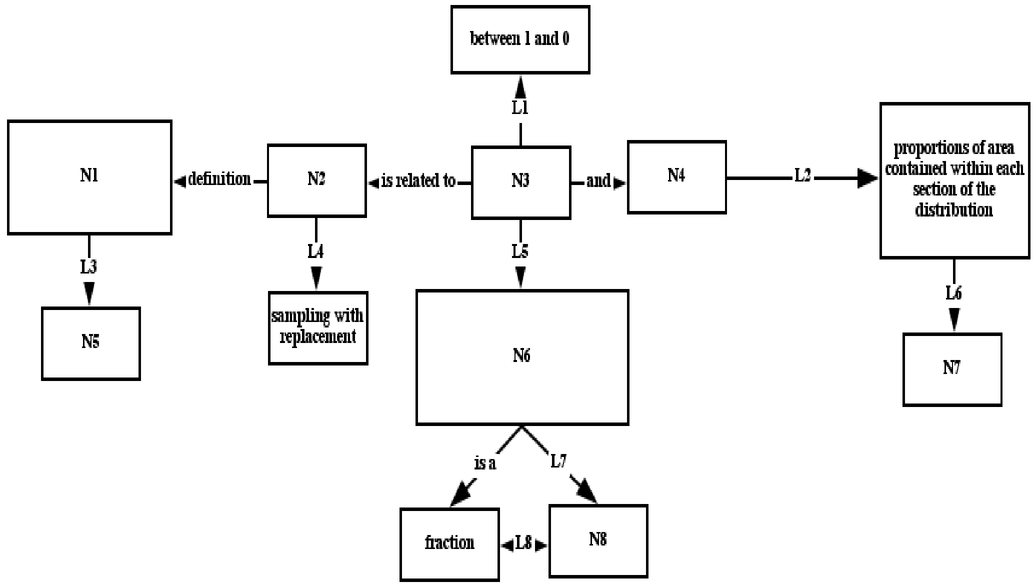
A. correspond to z-scores
B. Each individual in the population has an equal chance of being selected
C. no bias
D. **Probability**
E. proportion
F. Random Sampling
G. The Normal Distribution
H. When several different outcomes are possible, the probability of any particular outcome

N1. ___________	N5. ___________
N2. ___________	N6. ___________
N3. ___________	N7. ___________
N4. ___________	N8. ___________

Link Instructions: Match each of the words/phrases below with the link number they belong to on the Probability Map Worksheet.

I. can be described by
J. definition
K. insuring
L. is a
M. or
N. ranges
O. requires
P. these sections

L1. ___________	L5. ___________
L2. ___________	L6. ___________
L3. ___________	L7. ___________
L4. ___________	L8. ___________


between 1 and 0
L1
N1
definition
N2
is related to
N3
and
N4
L2
proportions of area contained within each section of the distribution
L3
L4
L5
L6
N5
sampling with replacement
N6
N7
is a
L7
fraction
L8
N8

Appendix B

Demographics Questionnaire

Please answer the following questions about you and your background. Circle the answer that best describes you or fill in the blank with the requested information.

1. What is your age? (In years.) __________

2. What is your sex? (Circle one.)
    1. Male
    2. Female
    3. Transsexual

3. What is (are) your major(s)?
____

4. What is (are) your minor(s)?
____

5. What is your college grade level? (Circle one.)
    1. Freshman
    2. Sophomore
    3. Junior
    4. Senior
    5. Post-baccalaureate
    6. Graduate student
    7. Other (please name): ____________________

6. What is your race/ethnicity? (Circle one.)
    1. Hispanic, Latino, or Spanish
    2. White
    3. Asian (e.g., Asian Indian, Chinese, Filipino, Japanese, Korean, Vietnamese)
    4. Black/African American
    5. American Indian (North, Central, or South American) or Alaskan Native
    6. Native Hawaiian
    7. Other Pacific Islander
    8. Other (please name): ____________________

7. How many undergraduate units have you already completed? __________

8. How many undergraduate statistics and/or research methodology courses have you taken before this class? (Circle one.)

1. 0 courses
2. 1 course
3. 2 courses
4. Other (please fill in how many) __________

9. Which undergraduate statistics and/or research methodology courses have you taken? (Please list all.)

____

____

____

10. How many math classes did you take in high school? (Circle one.)

1. 2 classes
2. 3 classes
3. 4 classes
4. Other (please fill in how many) __________

11. Which math classes did you take in high school? (Please list all.)

____

____

____

12. How many statistics classes did you take in high school? (Circle one.)

1. 0 classes
2. 1 class
3. 2 classes
4. Other (please fill in how many) __________

13. Which statistics classes did you take in high school? (Please list all.)

____

____

____

THANK YOU VERY MUCH FOR COMPLETING THIS SURVEY!

Appendix C

End of Training Concept Map Usage Questionnaire

This is an inventory of your concept map use over the first half of this semester. There are no right or wrong responses, only different ones. You can indicate whether or not you agree with the following statements by choosing the appropriate response. The last two questions are multiple-choice and not based on an agreement scale. Please respond to all of the items. Please respond honestly, your participation is important.

Strongly Disagree				**Strongly Agree**
1	**2**	**3**	**4**	**5**

1. I understand what a concept map is.

1 2 3 4 5

2. I understand the three types of concept maps discussed in class.

1 2 3 4 5

3. I understand when to use each type of concept map discussed in class.

1 2 3 4 5

4. The concept map homework assignments are useful for learning the material covered in my statistics course.

1 2 3 4 5

5. The concept map homework assignments have been stressful for me.

1 2 3 4 5

6. The concept map in-class lessons are useful for learning the material covered in my statistics course.

1 2 3 4 5

Strongly Disagree				**Strongly Agree**
1	**2**	**3**	**4**	**5**

---

7. The concept map in-class activities are useful for learning the material covered in my statistics course.

1 2 3 4 5

8. The "Concept Map Review" document was useful for clarifying the question(s) I had about concept mapping.

1 2 3 4 5

9. I include concept maps in the notes I take for my current statistics course.

1 2 3 4 5

10. I use concept maps, outside of class, to study the material covered in my statistics course.

1 2 3 4 5

11. I plan on using concept-mapping techniques to study statistics over the rest of the semester.

1 2 3 4 5

12. I plan on using concept-mapping techniques to study for my other courses over the rest of the semester.

1 2 3 4 5

---

13. The type of concept map I prefer using is a ___________.

a. chain map
b. net map
c. spoke map

14. Before learning about concept maps during this semester, I had already been taught concept-mapping techniques in another class.

a. Yes, in a prior high school class.
b. Yes, in a prior college class.
c. No.

<u>THANK YOU VERY MUCH FOR COMPLETING THIS INVENTORY!</u>

Appendix D

End of Semester Concept Map Usage Questionnaire

This is an inventory of your feelings toward using concept maps. There are no right or wrong responses - only different ones. You can indicate whether or not you agree with the following statements by choosing the appropriate response. There are also two multiple-choice questions and two yes/no questions that are not based on an agreement scale. Please respond honestly, your participation is important.

Strongly Disagree				**Strongly Agree**
1	**2**	**3**	**4**	**5**

1. The concept map homework assignments were useful for learning the material covered in this statistics course.

1 2 3 4 5

2. The concept map homework assignments were stressful for me.

1 2 3 4 5

3. I plan on using concept-mapping techniques to study for any future statistics courses that I may take.

1 2 3 4 5

4. I plan on using concept-mapping techniques to study for other future courses, besides statistics courses, that I may take.

1 2 3 4 5

5. I feel that using concept-mapping strategies was useful for increasing my theoretical understanding of statistics.

1 2 3 4 5

6. I feel that using concept-mapping strategies was useful for improving my academic performance in this statistics course.

1 2 3 4 5

Strongly Disagree				**Strongly Agree**
1	**2**	**3**	**4**	**5**

7. I feel that using concept-mapping strategies was useful for decreasing my anxiety towards statistics.

1	2	3	4	5

8. The type of concept map I prefer using is a ___________.

a. chain map
b. net map
c. spoke map

9. Before learning about concept maps during this semester, I had already been taught concept-mapping techniques in another class.

a. Yes, in a prior high school class.
b. Yes, in a prior college class.
c. No.

10. I included concept maps in the notes that I took in this statistics course.

a. Yes
b. No

11. I used concept maps, outside of class, to study the material covered over the course of the semester in this statistics course.

a. Yes
b. No

THANK YOU VERY MUCH FOR COMPLETING THIS INVENTORY!

Appendix E

Concept Map Rubric

	Exemplary **3**	**Exceeds Standard** **2**	**Adequately Meets Standard** **1**	**Below Standard** **0**
Content Organization	-Well organized. -Logical format that is easy to follow all of the time. -The main topic/concept is clear. -Contains appropriate sub-topics/concepts.	-Thoughtfully organized. -Format is easy to follow most of the time. -The main topic/concept is clear. -Contains appropriate sub-topics/concepts.	-Somewhat organized. -Format is difficult to follow. -The main topic/concept is unclear. -Contains inappropriate sub-topics/concepts.	-Confusing. -Format is very difficult to follow. -The main topic/concept is not clear at all. -Contains inappropriate sub-topics/concepts.
Structure	-Nodes demonstrate conceptual understanding. -Links are precisely labeled.	-Nodes are easy to follow but at times ideas are unclear. -Links are labeled.	-Nodes are difficult to follow. -Links are not labeled.	-Nodes are very difficult to follow. -No links.
Communication	-The structure provides a clear picture of the relationships between many ideas (5 or more).	-The structure provides a clear picture of the relationships between some ideas (between 3-4).	-The structure provides an unclear picture of few relationships between ideas (between 1-2).	-The structure is inappropriate.
Overall Presentation	-Presentation of information is clear and a high level of understanding can be achieved.	-Presentation of information is clear and a basic level of understanding can be achieved.	-Presentation of information is not totally clear, but a basic level of understanding can be achieved.	-Presentation of information is unclear and difficult to understand.