THE IMPACT OF CONCEPT MAPPING AS A LEARNING TOOL
ON STUDENT PERCEPTIONS OF AND EXPERIENCES
WITH INTRODUCTORY STATISTICS

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by
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TEACHING, LEARNING, AND CURRICULUM STUDIES

THE IMPACT OF CONCEPT MAPPING AS A LEARNING TOOL ON STUDENT PERCEPTIONS OF AND EXPERIENCES WITH INTRODUCTORY STATISTICS

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The ability to understand and utilize statistics concepts and techniques is paramount in today’s data-rich society. However, research suggests widespread difficulties and misconceptions as well as prevalent affective challenges, such as anxiety and lack of confidence, in the learning of basic statistics concepts at all levels of education. The purpose of this study was to document the experience of incorporating concept mapping as a learning tool to augment the learning of students in an undergraduate introductory statistics course in an adult learning setting. The study explored students’ experiences with concept mapping as a learning tool and examined the impact of this use of concept mapping on student perception by addressing the following questions: (a) How do students experience the learning of introductory statistical concepts through the use of concept mapping? (b) How do students in an introductory statistics course perceive the impact of their use of concept mapping on their ability to relate and apply important statistical concepts? Case study methodology was followed and data included observations, interviews, documents, questionnaires, and reflective journals. These data were analyzed in order to produce a detailed narrative describing the participants’ experiences and perceptions regarding the impact of concept mapping on the
learning of basic statistics concepts and to illuminate meaningful patterns from the
participants’ perspectives and experiences. Findings suggest students have mixed
experiences with the use of concept mapping, and they felt their ability to integrate
statistical concepts was enhanced through concept map use, but not their ability to apply
concepts for problem-solving.
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CHAPTER I
INTRODUCTION

The ability to understand, utilize, and apply statistics, particularly data analysis concepts and techniques, is paramount in today’s data rich society. While its own discipline, statistics is generally viewed as a body of concepts and techniques applied to analyze and interpret data and phenomena arising in all aspects of the world and daily life. The National Council of Teachers of Mathematics (NCTM) stated, “the amount of data available to help make decisions in business, politics, research, and everyday life is staggering” (NCTM, 2000, p. 48). Furthermore, NCTM contended, “students need to know about data analysis and related aspects of probability in order to reason statistically—skills necessary to becoming informed citizens and intelligent consumers” (p. 48).

Statistical reasoning, along with the related ideas of statistical literacy and statistical thinking, is a current focus in statistics education (Garfield & Ben-Zvi, 2007; Tishkovskaya & Lancaster, 2012; van der Merwe & Wilkinson, 2011; Zieffler et al., 2008). “Statistical literacy involves understanding and using the basic language and tools of statistics” (Garfield & Ben-Zvi, 2007, p. 380). Statistical reasoning is defined as “the way people reason with statistical ideas and make sense of statistical information. Statistical reasoning may involve connecting one concept to another” (Garfield & Ben-Zvi, 2007, p. 381). Statistical thinking is generally viewed as higher-order thinking and “involves an understanding of why and how statistical investigations are conducted and the ‘big ideas’ that underlie statistical investigations” (Ben-Zvi & Garfield, 2004, p. 7).
The emphasis on statistical literacy, reasoning, and thinking is being addressed in all levels of education. Scheaffer and Jacobbe (2014) contended that “statistical thinking should be an integral part of the knowledge base of every educated person, and the development of that knowledge must begin at the school [K–12] level” (p. 10). The current guiding force behind the design of statistics curriculum is the Guidelines for Assessment and Instruction in Statistics Education (GAISE) Report.

The GAISE project has been funded by a member initiative grant from the American Statistical Association (ASA) in 2003 to develop ASA-endorsed guidelines for assessment and instruction in statistics in the K–12 curriculum and for the introductory college statistics course. (Aliaga et al., 2005, p. 6)

In their guidelines for teaching introductory statistics, the authors of the college report recommended an emphasis on statistical literacy and the development of statistical thinking and a focus on conceptual understanding over procedural understanding (Aliaga et al., 2005, p. 6).

There has been an increasing trend in the number of learners who are exposed to this curriculum as enrollment in undergraduate statistics courses has increased substantially in recent years. Based on data from the 2010 Conference Board of Mathematical Sciences (CBMS) Survey, enrollment in introductory statistics courses taught in mathematics or statistics departments at both 2-year and 4-year institutions has increased 90% during the period 1995 through 2010 whereas overall undergraduate enrollment has increased only 37% (Blair, Kirkman, & Maxwell, 2013). This increase in statistics enrollments may even be understated due to the fact that enrollment in
introductory statistics courses offered by other departments, such as psychology, sociology, business, or economics, is not included in these enrollment figures. According to the survey, in Fall 2010, 449,000 students have been enrolled in introductory statistics courses offered by mathematics and statistics departments in 2-year and 4-year institutions, whereas only 59,000 students have been enrolled in upper level statistics courses at these same institutions (Blair et al., 2013). Therefore, the introductory statistics course is often the only exposure these students will have to key statistics concepts in their post-secondary education.

Despite the importance of statistical reasoning and the growing population of statistics learners, many individuals still experience difficulty with the learning of statistics. Misconceptions, difficulties in understanding, and negative feelings and attitudes regarding statistics are prevalent and widely documented (see e.g., Broers, 2001; Ismail & Chan, 2015; Murtonen, 2005; Onwuegbuzie & Wilson, 2003; Schau & Mattern, 1997). Research shows that students have difficulty interpreting and reasoning about data, are unable to interpret results in context, and are not capable of applying the appropriate techniques for a given situation (Mokros & Russell, 1995; Shaughnessy & Pfannkuch, 2002; Shaughnessy, Watson, Moritz, & Reading, 1999; Watson & Moritz, 1999, 2000a, 2000b). In addition, it has been found that students hold misconceptions regarding key statistical ideas, such as central tendency and variability (Broers, 2002; Ismail & Chan, 2015; Liu, Lin, & Tsai, 2009; Magee, 2014). Furthermore, the knowledge students demonstrate regarding these concepts often appears to be more procedural than conceptual in nature (McGatha, Cobb, & McClain, 2002).
Zieffler et al.’s (2008) review of the statistics education literature reports a substantial body of research documenting student’s “misconceptions, faulty intuitions, and errors in reasoning” (section 3.1). These difficulties range from mistaken ideas or basic procedural competency without conceptual understanding regarding specific concepts to a broad lack of statistical reasoning. Zieffler et al. also found the research to illuminate inconsistencies between what students can demonstrate on traditional assessments versus their general statistical reasoning abilities. This phenomenon may indicate that although there may be a basic level of understanding achieved, the ability to relate concepts and achieve higher-level cognitive outcomes is not being developed.

Research specific to undergraduate students confirms this chasm between procedural understanding and conceptual understanding (Qian, 2011). Retention of learned concepts is also an issue. Garfield and Ben-Zvi (2007) cited research that suggests students have only basic and partial recall of key statistical concepts after just a few weeks after the completion of study. This may be attributed to the fact that many introductory level courses at the undergraduate level address too many theories and methods for a single course offering (Qian, 2011). Moreover, the research focused on undergraduate statistics learners widely acknowledges these factors to be confounded with statistics anxiety, attitudes toward statistics, and previous negative experiences with mathematics or statistics.

The affective challenges that students encounter while studying statistics have been widely documented in the literature. Murtonen and Lehtinen (2003) administered an open-ended questionnaire and found that students considered statistics to be a difficult
subject and viewed statistics as the most abstract subject (p. 175). Statistics anxiety is a major deterrent to understanding statistical concepts. Onwuegbuzie defined statistics anxiety as “an anxiety that occurs when a student encounters statistics in any form and at any level” (Onwuegbuzie & Wilson, 2003, p. 196). Hong and Karstensson (2002) reported,

Anxiety about statistics courses can result in deferring taking required statistics courses until just before graduation or in avoidance of statistics courses necessary for future professional advancement. High levels of perceived difficulty on statistics tests and statistics test anxiety can also have negative impacts on statistics test performance. (pp. 348-349)

Research has demonstrated that additional affective factors, such as beliefs, attitudes, predispositions based on prior learning experiences, personal experience, goals, subjective perceptions, confidence, and motivation, also greatly affect students’ abilities to learn and apply statistical reasoning skills (Gal & Ginsburg, 1994; Gal, Ginsburg, & Schau, 1997; Gordon, 1995). For example, Perepiczka, Chandler, and Becerra (2011) found that attitudes toward statistics along with statistics anxiety significantly relate to self-efficacy to learn statistics, which Finney and Schraw (2003) linked to course performance measures.

These considerations are driving the current trend in statistics education toward the development of statistical reasoning and active learning. Contemporary research in statistics education offers several suggestions for improving the learning of introductory
statistics based on both studies of alternative instructional and learning strategies as well as cognitive and constructivist theory (Tishkovskaya & Lancaster, 2012).

According to Broers, “to be able to reason statistically, a student needs to possess knowledge of an integrated body of concepts and ideas” (2001, Section 1). This focus on connecting statistical concepts is apparent in instructional strategies and the research. Garfield and Ben-Zvi (2007) recommended introducing concepts informally in data driven ways and then connecting these ideas formally to theory. They also endorsed providing opportunities for key concepts, such as center, variability, and distribution, to be explored together. These strategies promote conceptual understanding and the relatedness of ideas by placing the emphasis on statistical reasoning over disjointed formulas, methods, and techniques.

Qian contended, “students must be engaged in the learning process in order to facilitate retention” (2011, p. 114). This “active learning” is a hallmark of constructivist thought. Tishkovskaya and Lancaster (2012) stated that reforms in statistics education have been based on cognitive constructivism—the theory of “learning as actively constructing knowledge which interacts with previous knowledge, beliefs, and intuitions” (p. 12). In addition, social constructivist theories have also framed these reforms. Active learning provides opportunities to gain understanding through both cognitive and social construction. Examples of active learning strategies include collaborative and cooperative activities, problem-based learning, simulations, the use of technology, and visual representations, such as graphic organizers.
Concept Maps

Concept maps may be used as an active learning strategy. A concept map is a graphical tool for organizing and representing knowledge developed by Novak as a schematic approach to the representation of relational concepts (Novak & Gowin, 1984; Novak & Musonda, 1991). A concept map consists of concepts placed in nodes connected by links with propositions representing and identifying the relationships between the nodes. Concept maps are organized hierarchically from the most general to more detailed and focused ideas (sub-concepts). Novak and Cañas (2008) developed the concept map reproduced in Figure 1 to illustrate the underlying theory, structure and general characteristics of concept maps.

Figure 1. Concept map of concept maps reproduced from Novak and Cañas (2008).
Novak and Cañas (2008) described a general approach to the development of a concept map. They recommend first devising a focus question within a domain. A focus question specifically identifies the issue that the mapper is trying to resolve or understand. The next phase of the concept mapping process is to identify the key concepts that relate to this domain. A concept is defined as “a perceived regularity in events or objects, or records of events or objects, designated by a label” (Novak & Cañas, 2008, Introduction section). A concept may be thought of as the mental image that emerges when you hear a word. These concepts are listed in order from the broadest concept at the top of the list to more specific concepts at the bottom of the list. Novak and Cañas referred to this list as the parking lot. In the next phase, a tentative concept map is constructed by placing the concepts in nodes, typically, ovals or blocks, and by arranging these concepts in a hierarchical order. Then the concepts are connected by lines or arrows to indicate relationships between the concepts. Linking words are placed on the lines to describe the relationship between the two concepts. The set of concepts and the linking words connecting them forms a proposition. “Propositions are statements about some object or event in the universe, either naturally occurring or constructed” (Novak & Cañas, 2008, introduction section). Novak and Cañas cautioned that this process is iterative, and several revisions of the concept map are often necessary to accurately portray the desired hierarchy and propositions.

As the concept map becomes more hierarchically structured, different map segments begin to form. Cross-links are lines that form propositions between concepts in different segments of the concept map. Novak and Cañas (2008) viewed cross-links as
important for demonstrating relational knowledge between different segments or subdomains in the map, and they believed that creative thinking and deep knowledge integration occurs in this phase. A final step in constructing a concept map is adding specific examples to illustrate a given concept. These examples are typically not encased in nodes to distinguish them from concepts.

Concept maps have had a substantial history in science education having been formally developed and introduced by Novak in the early 1970s in a 12-year longitudinal study of science learning (Novak & Musonda, 1991). The goal of the study was to examine changes in students’ understanding of science concepts. Concept mapping began as a result of looking for ways to organize information from many interviews and transcripts of learning of science concepts of first and second graders. A key objective of that organization of material was to be able to clearly examine and illustrate students’ concept meanings and deep understandings. Novak originally used concept maps to examine and demonstrate changes in understanding over time. This particular use of concept mapping, as assessment and evaluation, has remained prominent (Grunow, 1998; Lavigne, 2005; Lavigne, Salkind, & Yan, 2008; Merrill, 1987; Michael, 1994; Roberts, 1999; Wholeben, 1994; Williams, 1998). Also, concept mapping has been used to improve teacher effectiveness through instructional design, feedback, assessment and evaluation of content knowledge, and curriculum development (Grunow, 1998; Weinholtz, 1995).

Additionally, concept mapping has found favor as an instructional and learning strategy. Throughout the course of Novak’s longitudinal study, it was “found that
concept maps were not only a useful tool to represent changes in the knowledge structure
of students over time, but also helped them ‘learn how to learn’” (Novak, 1990, p. 941).
Specifically, Novak asserted,

Undoubtedly, we may develop new concept relationships in the process of
drawing concept maps, especially if we seek actively to construct propositional
relationships between concepts that were not previously recognized as related:
Students and teachers constructing concept maps often remark that they recognize
new relationships and hence new meanings (or at least meanings they did not
consciously hold before making the map). (Novak & Gowin, 1984, p. 17)

The research suggests several potential benefits of the use of concept mapping as
a learning tool. The use of concept maps is thought to reflect, and deepen, a person’s
understanding of a subject because it is necessary to not only list concepts but to link
them by their relationships and show connectedness of ideas (Baroody & Bartels, 2000;
Afamasaga-Fuata’i (2009) reported students’ perceptions that concept mapping “demands
a much deeper understanding of interconnections than simply knowing what the main
concepts and formulas are” (p. 255). These connections and knowledge frameworks built
through the use of concept mapping in turn help in the long-term retention of knowledge
(Novak, 1995). Roberts (1999) found that the examination of student-created concept
maps illuminated misconceptions in the student’s understanding of basic statistic
concepts. Furthermore, Baroody and Bartels (2000) found that not only do concept maps
reveal misconceptions, but the act of concept mapping often allows the students to
discover these misconceptions and gaps in knowledge for themselves. Novak and Gowin (1984) saw this self-reflection and active learning as key benefits of concept mapping.

Novak’s views of conceptual understanding and learning have been greatly influenced by Ausubel’s view of meaningful learning and his theories of cognitive learning. Ausubel (1963) asserted that meaningful learning, as opposed to rote learning that is often temporary and isolated from existing knowledge, happens when new material is integrated with existing knowledge structures. Furthermore, he contended the occurrence of meaningful learning requires three conditions: that the material to be learned is actually capable of being practically related to existing cognitive structures, the individual has the pertinent cognitive structures to which to relate the new material, and the individual has the desire to do so.

The main characteristics of Ausubel’s (1963) cognitive learning theory include subsumption-obliterative, derivative, and correlative; superordinate learning; combinatorial meanings; progressive differentiation; integrative reconciliation; and advance organizers. Derivative subsumption, correlative subsumption, superordinate learning, and combinatorial meanings may be classified as four processes by which meaningful learning may come about. The other features, progressive differentiation, integrative reconciliation; and advance organizers, are more pedagogical in nature.

Subsumption is the process of incorporating new materials into existing cognitive structures. The first stage of subsumption may be described as a general anchoring of new material to some existing concept, called the subsuming concept. Ausubel (1963) distinguished two main types of subsumption: derivative and correlative. Derivative
subsumption represents learning new material that is an instance or illustration of a previously learned concept while correlative subsumption occurs when a new idea is related to, but not a direct extension of, an existing subsuming concept. The learning or integration of this new concept generally requires modification or extension of the subsuming concept. The second stage of subsumption is called obliterative subsumption. As the new material is linked to existing concepts, the details of the new material tend to be forgotten, or generalized, until they are indistinguishable from the subsuming concept (Ausubel, 1963, p. 25). Ausubel viewed obliterative subsumption as a necessary evil of meaningful learning, for as this generalizing serves to expand and deepen the subsuming concept it also causes the loss of unique details of the new material; and he believed that the challenge of any pedagogical approach is to counter this tendency. Ausubel believed the occurrence of obliterative subsumption in the case of derivative subsumption is fairly rapid and harmless as the detailed concept can be easily reconstructed as necessary from the subsuming concept. On the other hand, Ausubel stated, “when correlative propositions lose their identifiability and can no longer be dissociated from their subsumers, a genuine loss of knowledge occurs” (1963, p. 53).

Two other processes involved in meaningful learning are superordinate learning and combinatorial meanings. Superordinate learning is counter to subsumption, where new ideas are absorbed under existing concepts. Superordinate learning occurs when several existing concepts are synthesized under a newly introduced umbrella-like concept (Ausubel, 1968, p. 53). Combinatorial learning represents the learning of new concepts that are neither subordinate nor superordinate. While not directly relatable to particular
existing concepts, these new meanings “consist of sensible combinations of previously learned ideas that can be nonarbitrarily related to a broad background of generally relevant content in cognitive structure” (Ausubel & Robinson, 1969, p. 67). It is Ausubel’s belief that combinatorial meanings are generally more difficult to learn because their relationship is not explicitly representative of the hierarchical nature of cognitive structures as are subsuming or superordinate concepts. Ausubel offered models and metaphors as two ways learners attempt to process combinatorial meanings.

Progressive differentiation describes the presentation of new concepts first in their broadest and most inclusive form and then in increasingly specified and detailed forms. Integrative reconciliation endorses presenting concepts in an integrated, non-compartmentalized way so that commonalties and significant differences in related ideas may be illuminated and potential contradictions may be reconciled. These methods, or principles as Ausubel (1963) called them, are not mutually exclusive. In fact, Ausubel’s strategy of advance organizers encompasses both principles. Advance organizers are vehicles introduced prior to the planned learning experience that provide a generalized and abstract framework. They are thought to provide subsuming concepts to which to relate the concepts to be introduced. Ausubel recommended a hierarchical series of organizers, starting at the highest level, to allow for the progressive differentiation of material. In addition to the subsuming concepts, comparative organizers provide similarities and differences between the new information and the related existing concepts in order to foster integrative reconciliation.
The facets of Ausubel’s theories that have greatly influenced Novak’s development of concept maps include the following:

- “The most important single factor influencing learning is what the learner already knows” (Ausubel, 1968, epigraph).
- New meanings are “acquired through assimilation into existing concept/propositional frameworks” (Novak, 1990, p. 938).
- The cognitive structures of an individual are organized hierarchically.

Based on this view of the hierarchical and relational nature of concept learning, Novak asserted that “learning approaches that facilitate this process significantly enhance the learning capability” (1995, p. 233).

**Rationale for the Study**

I have been teaching introductory statistics courses at the undergraduate level for 25 years, most of which has been in an adult learner degree-granting program of a small liberal arts college. The majority of the students in my classes are characterized as nontraditional students. The National Center for Education Statistics defines nontraditional students as meeting at least one of seven characteristics: delayed postsecondary enrollment; part-time college enrollment; full-time employment; financial independence based on financial aid criteria; has dependents other than a spouse; single parent status; does not have a standard high school diploma (Horn, 1996). Malcolm Knowles, whose theory of andragogy is one of the most prominent adult learning theories, details six principles of this population of learners: (a) The need to know. Adults need to understand the reason for knowing something before they will attempt to
learn it; (b) The learner’s self-concept. Adults need to be viewed by others as capable of self-direction in their learning; (c) The role of the learners’ experiences. Adults have both volume and quality of experience that may be used in learning new concepts; (d) Readiness to learn. Adults will learn something when they have a relevant and immediate need to learn it; (e) Orientation to learning. Adults are problem-centered as opposed to content-centered in their learning; and (f) Motivation. Adults are more motivated by internal factors, such as self-image and quality of life, than external factors (Knowles, Holton, & Swanson, 2015, pp. 43-47).

My course has evolved over the years in response to the recommendations of the statistics education community to emphasize conceptual understanding, data analysis, and active learning and in awareness of the specific characteristics and needs of my adult learners. However, I have continued to see students struggle with many of the aforementioned challenges and affective issues cited in the statistics education literature. To further inform my perspective, I conducted a study preceding this research to gain a student perspective on these phenomena. This pilot study took a phenomenological approach to understanding the essence of the experience of statistics instruction as perceived by postsecondary students. Two graduate students participated in in-depth interviews to share their previous experiences with statistics instruction at the undergraduate level. Detailed results of the study are included in the Methodology chapter of this study. Several key findings from the study prompted me to consider introducing concept mapping into my course. The participants expressed a perspective of having procedural understandings, but little conceptual understanding; a satisfaction with
having instructional aids such as outlines and organizers; and an eagerness to move away
from traditional lecturing approaches and presentation of formulas without connections to
more active learning approaches. Key elements of concept maps, such as their potential
to engender meaningful learning, their hierarchical structure, and their nature of
self-directed active learning, appear to be aligned with the findings of this pilot study.

What would the effects be of introducing concept mapping in my introductory statistics
course? Would students have a more positive experience with the learning of statistics
and would concept mapping influence their perceptions of their knowledge of statistics
and their ability to apply statistical concepts?

**Statement of the Problem**

A consensus that might be derived from much of the research related to statistics
learning is that many students have difficulty grasping statistical concepts and
demonstrate negative attitudes towards the topic, courses, and/or application of statistics
(Ben-Zvi & Garfield, 2004; Zieffler et al., 2008). The goal of this study is to introduce
college students to a learning tool to augment their learning of introductory statistical
concepts that might specifically address these prevalent student difficulties.

**Purpose of the Study and Research Questions**

The purposes of this study are to explore students’ experiences with concept
mapping as a learning tool for introductory statistics at the undergraduate level and to
examine the impact of this use of concept mapping on student perception. Regarding
student perception, the study investigates whether the use of concept mapping affects
students’ views of their knowledge of, their ability to use, and their attitudes about basic statistical concepts. The study addresses the following questions:

1. How do students experience the learning of introductory statistical concepts through the use of concept mapping?
2. How do students in an introductory statistics course perceive the impact of their use of concept mapping on their ability to relate and apply important statistical concepts?

**Theoretical Basis and Assumptions**

The theoretical framework of this study consists of affect and constructivism. It is widely agreed upon that cognition is greatly affected by non-cognitive factors. Because of this reason and the fact that my research questions focus on how students experience and perceive a particular learning strategy, it is imperative that we consider the role of affect in learning statistics. Constructivism is a theory of knowledge and learning that is central to contemporary education reform and which encompasses several closely related schools of thought. Novak’s development of concept mapping was deeply influenced by constructivist theories, and in particular, Ausubel’s theories of meaningful learning and cognitive structure.

**The Role of Affect in Learning Statistics**

Based upon their review of the statistics education literature, Gal and Ginsburg (1994) provided four examples of how affective issues may impact the statistics learning experience:
1. Fear or discomfort may negatively impact the development of “flexible problem-solving and data-analyzing skills” (¶13).

2. Students’ preconceptions about their own learning abilities, math and test anxiety, and “beliefs about the relevance (or lack thereof) of statistics for their future career or job plans” (¶14) also may impact their problem-solving.

3. “Beliefs and attitudes related to math may play a powerful role in affective responses to statistics” (¶15) which in turn may be counterproductive to statistics learning.

4. Initial confusion or frustration may escalate into “loss of confidence and panic over the sense of lack of control of one’s own comprehension” (¶16) leading to a withdrawal from active learning.

Numerous empirical studies have linked various affective factors, such as motivation, attitudes toward mathematics and statistics, mathematics anxiety, and statistics anxiety with achievement in statistics courses (Dempster & McCorry, 2009; Finney & Schraw, 2003; Gordon, 1995; Kaplan, 2006; Nasser, 2004; Scott, 2001; Tremblay, Gardner, & Heipel, 2000; Vanhoof et al., 2006).

Moreover, there is an abundance of anecdotal evidence that suggests attitudes about statistics affect students’ experiences with statistics courses. Common examples include students delaying taking required statistics courses as long as possible or even choosing a particular field of study in order to avoid a statistics course altogether. In fact, negative feelings regarding statistics have become so prevalent in popular culture that a Rosenthal (1992) editorial for the Consortium for Mathematics and its Applications
(COMAP) was inspired by a common student replacement of the word statistics with the word sadistics and there is even a popular introductory statistics textbook entitled, *Statistics for People Who (Think They) Hate Statistics* (Salkind, 2014).

**Constructivism**

The fundamental tenets of constructivism include that knowledge is actively constructed and that prior knowledge impacts this learning process. According to Novak and Cañas (2007), “constructivist epistemology sees knowledge not as discovered absolute truths but rather knowledge is seen as a human construction that evolves as new ideas and new ways of looking at the world evolve” (p. 33). This notion of knowledge is in direct contrast to behaviorist theories that believe knowledge is passively received and absolute.

Piaget generally is credited for providing the foundation of constructivist theories through his models of cognitive development. According to Piaget (1952), cognitive structures, or schema, develop through a cycle of assimilation and accommodation. Schema may be thought of as a basic unit of knowledge related to a single aspect of the world, or in other words, it represents a mental process used to understand and respond in a particular situation. Assimilation refers to the integration of new concepts by way of existing schemas. Accommodation refers to the modification of existing cognitive structures to explain discrepancies between the environment and existing structures. Knowledge, then, is believed to be actively constructed through this cycle of assimilation and accommodation. Piaget asserted learning to be an individual process taking place inside the mind of the individual and based upon the personal experiences and
dispositions of the individual. While Piaget does not exclude the potentiality of social interaction, it is the individual interpretation of that interaction that creates knowledge.

Sociocultural theorists, led by Vygotsky, agree that knowledge must be constructed. However, in contrast to Piaget, the belief is that the construction takes place through social interaction and then is internalized by the individual (Vygotsky, 1978). So, unlike Piaget who views an individual’s knowledge creation as occurring internally, Vygotsky regarded knowledge creation as happening both internally and externally. Vygotsky viewed knowledge creation as occurring through the lens of language and culture which are social manifestations. Therefore, collaboration is essential to knowledge creation. A key principle of Vygotsky’s theory is the Zone of Proximal Development (ZPD). The Zone of Proximal Development represents the difference between what a person knows and what that person can learn with the appropriate guidance or collaboration.

Radical constructivists, headed by von Glasersfeld, emphasize the subjective nature of knowledge. Von Glasersfeld maintained, “cognition serves the subject’s organization of the experiential world, not the discovery of an objective ontological reality” (1995, p. 51). Furthermore, knowledge is gauged by its viability, the extent to which it fits in with the individual’s experiences and makes sense in the intended context.

**Relating Concept Mapping as a Learning Tool to Constructivism**

Novak’s interpretation of Ausubel’s theories focus on the concept of what it is to learn something meaningfully as well as on his cognitive theories of learning that rely on the hierarchical and relational nature of learning. In this way, concept mapping is very
consistent with constructivist thought. Concept mapping requires the creator of the map to represent knowledge through a hierarchy of concepts and through interrelatedness, or linking, of those concepts. This representation is in line with the constructivist view that knowledge construction is heavily dependent on the individual connecting new concepts with existing knowledge. This corresponds to Novak’s fundamental epistemological assumption that “knowledge is a human construction of concepts and concept relationships” (Novak & Musonda, 1991, p. 129). The act of creating a concept map is a physical manifestation of this construction. Explicitly identifying the concepts and links in a map requires active learning, reflection, and ownership of the ideas contained in the map—all hallmarks of constructivist thought. Baroody and Bartels noted the benefits to metacognition as a result of the reflective component concept mapping: “In attempting to draw a concept map, students often quickly recognize for themselves what concepts and connections are not clearly or completely understood. This self-evaluation may prompt them to reason out a connection, research the topic, or ask questions” (2000, p. 607).

Concept mapping as a learning tool is congruent to social constructivism and socio-cultural theory. Research suggests that the dialogue and reflection that occur from defending one’s concept map or from collaboratively building concept maps provoke deeper understandings (Novak, 1995) and “can underscore the fact that the construction of knowledge is very much a social process” (Baroody & Bartels, 2000, p. 608). Concept mapping is further related to Vygotsky’s sociocultural framework through the principle of semiotic mediation, the use of signs and symbols as a part of psychological development. Vygotsky viewed the use of semiotic tools as essential to the mediation of
the internal and external aspects of knowledge creation. In addition to language, Vygotsky viewed semiotic means to include drawings, diagrams, and maps. Tools, such as concept mapping, then, are seen as essential to “the appropriation of knowledge through representational activity by the developing individual” (John-Steiner & Mann, 1996, p. 193).

Baroody and Bartels (2000) demonstrated the consistency of concept mapping with radical constructivism in that the evolution of an individual’s concept map as ideas become more sophisticated demonstrates the changeable or subjective nature of knowledge (p. 608).

**Significance of the Study**

The field of statistics is relatively new compared to other areas of mathematics, and its introduction into mainstream curricula is even more recent. Substantial research in statistics education and, particularly, into students’ understanding of statistical concepts, has just begun over the last several decades and had been regarded as being in the early stages of development as recent as a little over a decade ago (Heaton & Mickelson, 2002). The body of statistics education research has grown significantly in the past two decades, but there continues to be a need for research focused on improving the learning of statistics. The importance of this area of research, and the significance of this study, may be attributed to several issues.

Quantitative literacy, or numeracy, has become essential to nearly everyone’s work and daily life. In fact, Steen (1999) noted quantitative methods are “the dominant form of acceptable evidence in all areas of public life” (p. 10). Beginning in 1989 with
their *Curriculum and Evaluation Standards for School Mathematics*, NCTM has provided standards for statistics across all grade bands. *Principles and Standards for School Mathematics* (NCTM, 2000) expands on these standards to create data analysis standards aimed at developing in students a progressively more sophisticated understanding of statistical concepts, an “ability to judge the validity of arguments that are based on data, such as those that appear in the press” (p. 51), and a “way for students to connect mathematics with other school subjects and with experiences in their daily lives” (p. 48).

Current emphases in the statistics education reform movement include pedagogical reforms aimed toward developing conceptual understanding, introductory level course content, and enriching instructional techniques (Tishkovskaya & Lancaster, 2012). The basic components of this study, the use of an instructional/learning tool that research has shown to encourage and enhance conceptual understanding and the focus on an introductory statistics course, fit well into the statistics education reform framework. Therefore, the results of this study may contribute meaningfully to this effort.

A better awareness of students’ perceptions regarding their experiences with statistics learning, including specific strategies such as concept mapping, is necessary and relevant for improving student understanding of statistics through appropriate instruction and learning opportunities. This information may inform curriculum decisions, may influence instructional approaches and philosophies of current teachers, and may impact teacher education programs. According to Brookfield (1995), “awareness of how
students are experiencing learning is the foundational, first-order knowledge we need to do good work as teachers” (p. 94).

In summary, the ease and abundance of graphical displays and data presentation afforded by technology and the increasingly large number of students studying these concepts, combined with documented deficiencies of most adults in the area of statistics, behoove improved understanding and development of student understanding of statistics. This study is designed to contribute insight and strategies to enhance this understanding.
CHAPTER II
REVIEW OF RELATED LITERATURE

This chapter presents a review of the literature aligned with the frameworks introduced in the prior chapter. The first section reviews the research concerning the learning of introductory statistics. The next section addresses the role of affect in statistics. The third section describes adult learning of mathematics and statistics. The fourth section reviews the literature on concept mapping with an emphasis on the influence of concept mapping on the development of statistical understanding. The final section relates the existing research to the aims of this study.

Statistics Learning

Factors including the importance of statistical literacy and reasoning in contemporary society, increased presence of statistics in the curriculum, and the pervasiveness of misconceptions, negative attitudes, and cognitive challenges regarding statistics have brought the examination of how students learn statistics to the forefront of the literature.

The literature in statistics education research is often grouped into categories (Gal & Ginsburg, 1994; Shaughnessy, 1992; Zieffler et al., 2008). Zieffler et al. described four basic classifications: studies that investigate misconceptions and faulty reasoning, studies that assess cognitive outcomes, studies that focus on non-cognitive outcomes, and studies that examine instructional strategies, particularly at the college level (Section 1). When the authors conducted their literature review nearly a decade ago, they had contended that research in the first area was mostly saturated and recommended a focus
on research into cognitive outcomes, such as statistical thinking and reasoning. Indeed, in recent years, this focus has grown markedly within the literature. Gal and Ginsburg endorsed more research into the third area of research, that of non-cognitive, or affective, outcomes (Gal & Ginsburg, 1994; Gal et al., 1997). The current study is consistent with both of these recommendations in that the proposed instructional strategy of concept mapping stresses conceptual thinking and reasoning, and the research questions include a focus on the perceptions and beliefs of the learners.

Much of the research in statistics education focuses on the evaluation and interpretation of student understanding of particular statistical concepts. Mokros and Russell (1995) and Watson and Moritz (2000b) have explored student understanding of the concept of average through observation, interviews, and examination of student problem solving. Shaughnessy et al. (1999) and Shaughnessy and Pfannkuch (2002) presented studies of how students construct meaning for the concept of variation. Other particular statistical concepts examined in terms of student knowledge include comparison of two data sets and sampling (Watson & Moritz, 1999, 2000a). A key finding in much of this research is the predominance among students of procedural knowledge over conceptual knowledge of these statistical concepts. Regarding the mean, for example, the findings of these studies indicate that many students view the formula for the mean as a mathematical algorithm that produces a specific number. However, these students have difficulty interpreting the meaning of the concept or of the value obtained, and, often, “when the students calculated the mean, they did so without considering its appropriateness with respect to the task situation” (McGatha et al., 2002,
In addition, Broers (2002) and McGatha et al. (2002) examined student performance regarding multiple statistical concepts and general data analysis procedures. These studies indicate that students have difficulty interpreting and reasoning about data, and the findings provide further evidence that students’ understandings are largely procedural.

Another primary focus of the research in statistics education involves discussion of various approaches to statistics education. Shaughnessy and Pfannkuch (2002) and Konold and Pollatsek (2002) examined strategies for improving the instruction and understanding of specific statistical concepts. In contrast, Chick and Watson (2002) presented a case study exploring the effectiveness of collaborative learning on general statistical thinking. Their analysis gauges the effectiveness of a collaborative learning approach primarily in terms of cognitive outcomes. These studies suggest that tasks and settings that require and encourage students to produce or collect their own data, to work with real-world problems, and to engage in collaboration and discussion motivate deeper understandings of the statistical concepts examined in the research. Furthermore, guidance and appropriate questioning by the instructor are seen as vital to the development of statistical reasoning skills in students (Chick & Watson, 2002; Shaughnessy & Pfannkuch, 2002).

Much current research in statistics instruction involves the use of technology, including computer-based curriculum, on-line resources, web-based delivery, statistical software, and spreadsheet applications, in statistics instruction (Ben-Zvi, 2000; A. Porter, Griffiths, & Hedberg, 2003; Shotwell & Apigian, 2015; Velleman, 2000). While many of
the reports present summaries of resources with only a few providing data on their
effectiveness (Schuyten, Dekeyser, & Goeminne, 1999), in those that did gauge
effectiveness, there have been inconsistent findings in the level of effectiveness of these
technology tools to improve learning. However, research shows the use of technology in
active learning activities is typically well-received by students, and web-based delivery of
curriculum appears to result in achievement that is at least comparable with a more
traditional mode of delivery.

Garfield and Ben-Zvi (2007) noted the shift in both statistics education instruction
and research toward cultivating statistical reasoning. One of the hallmarks of this change
is an increased emphasis on a narrower focus. That is, instruction and research are
moving towards deeper and more conceptual understanding of several “big ideas” in
statistics with less emphasis on multiple methods and formulas. Other recent studies
have examined the effectiveness of specific instructional strategies on the development of
statistical reasoning. Ramirez-Faghiih (2012) has examined the effect on statistical
reasoning of having students conduct their own investigations. This activity requires the
use of real data and the necessity to relate several statistical concepts in order to perform
the appropriate analysis of the data. Qualitative results indicate that students perceive an
increase in their ability to reason statistically. In an implementation of learning projects
into undergraduate statistics courses, Moreira Da Silva and Pinto (2014) have found that
the learning projects have impacted the ability of students to relate statistical concepts
and practical applications.
Garfield and Ben-Zvi (2007) contended that the existing body of research in statistics education conveys “the difficulties students have in learning statistics and the need to revise traditional methods of teaching” (p. 389). The literature suggests that students need to construct their own knowledge through active learning, practice, the use of technology, and consistent feedback. In addition, research and learning strategies must continue to offer opportunities to identify misconceptions, faulty reasoning, and gaps in knowledge while developing statistical reasoning skills.

**Affective Factors in Statistics Education**

In recent decades, there has been an increasing focus on affective considerations in statistics education. In its early stages, most of the research focusing on non-cognitive issues in statistics education focused on statistics anxiety. While this focus still is represented strongly in the literature, other issues, such as attitudes towards statistics, perceptions of its utility, and motivation, also have gained attention.

Onwuegbuzie and Wilson’s (2003) review of the literature on statistics anxiety in undergraduates found numerous empirical studies that demonstrate a relationship between statistics anxiety and course performance. Onwuegbuzie and Wilson also reported that statistics anxiety is linked to other issues such as course avoidance and degree completion. There have been several studies to determine the factors that may be related to statistics anxiety. Baloğlu (2003) found that previous mathematics experience and age are significantly related to statistics anxiety. Onwuegbuzie (2000) performed a multivariate analysis to investigate how self-perception is related to statistics anxiety. The author examined these constructs by looking at the specific dimensions of the
constructs. The six dimensions of statistics anxiety as measured by the Statistical Anxiety Rating Scale (STARS) are worth of statistics, interpretation anxiety, test and class anxiety, computational self-concept, fear of asking for help, and fear of the statistics instructor. The dimensions of self-perception were measured by the Self-Perception Profile for College Students (SPPCS). The researcher chose seven subscales of the instrument: perceived creativity, perceived intellectual ability, perceived scholastic competence, perceived job competence, perceived social acceptance, perceived ability to laugh at oneself (humor), and perceived global self-worth. The researcher found that three dimensions of self-perception—perceived creativity, perceived intellectual ability, and perceived scholastic competence—were significantly correlated to all six dimensions of statistics anxiety.

In attempting to understand and perhaps provide interventions for statistics anxiety, some of the research regarding statistics anxiety examines its relationship to other types of anxiety, such as general, mathematics, and test anxiety with varying results. Murtonen (2005, p. 13) suggested no significant correlation between statistics anxiety and general anxiety. Hong and Karstensson (2002) discussed conflicting research on the relationship between mathematics anxiety and ability and statistics course anxiety. However, research regarding mathematics anxiety has revealed patterns of behavior among mathematics-anxious students that were similar to those of statistics-anxious students (Ashcraft, 2002).

Non-cognitive factors in addition to statistics anxiety, such as motivation, beliefs, and attitudes, are correlated to achievement in introductory statistics courses. Tremblay
et al. (2000) developed a quantitative model relating various affective measures as well as previous performance measures to final exam scores in an introductory statistics course. Results showed significance in the relationships of motivation, aptitude, and anxiety with performance in the introductory statistics course. Similarly, Nasser (2004) developed a structural model to explain exam scores of preservice teachers in introductory statistics utilizing commonly used validated measures of attitudes towards mathematics and statistics, statistics and mathematics anxiety, motivation, and mathematical aptitude as factors. The most significant variable of the model explaining achievement was found to be mathematical aptitude; however, a statistically significant model to explain achievement in the introductory statistic course contained the variables representing attitudes toward mathematics and statistics, mathematics anxiety, and motivation, in addition to mathematical aptitude. Vanhoof et al. (2006) examined the relationship between attitudes toward statistics as measured by the Attitudes Toward Statistics (ATS) scale and statistics exam results and found significant relationships between various attitude constructs and both short and long-term exam results. Scott (2001) used a different instrument, the Survey of Attitudes Toward Statistics (SATS), to develop models similar to the others linking various affective measures with performance.

Gal and Ginsburg (1994) illuminated the role that non-cognitive issues have in statistics learning, and they developed a framework for assessing these issues based on their conjecture that factors such as beliefs, attitudes, statistics anxiety, and predispositions based on prior learning experiences have the ability to hinder statistics learning. Gordon (1995) developed a conceptual model based on questionnaires and
interviews with university students enrolled in statistics courses that demonstrates the confounding of emotional factors with the learning experience. Gordon’s model was based in activity theory that “posits a view of learning in which personal experience, goals, subjective perceptions, and socio-historical factors are interwoven” (¶ 12).

Dempster and McCorry (2009) investigated a model to explain achievement over a two-year undergraduate statistics curriculum for psychology students using subscales from the SATS as well as researcher-designed scales focused on previous experience with mathematics, statistics, and computing. They found that achievement was related to students’ perceived cognitive competence as well as specific attitudes held at the time of the assessment. Based on these findings, the authors suggested that there should be interventions focused on the attitude of cognitive competence. “We need to help students to believe that they have the intellectual capacity to cope with the demands of the statistics curriculum and we need to maintain this attitude throughout the curriculum” (Dempster & McCorry, 2009, Section 4).

Finney and Schraw (2003) developed two other measures of non-cognitive factors as related to statistics. When considering factors that affect performance from within a motivational framework, they noted that self-efficacy is related to “performance, effort, persistence, perseverance, and future enrollment in courses within a domain” (p. 162), all challenges in the area of statistics education. Therefore, they developed and validated two scales to measure self-efficacy in introductory statistics learners. Current statistics self-efficacy (CSSE) is defined as “confidence in one’s abilities to solve specific tasks related to statistics” (Finney & Schraw, 2003, p. 164) and self-efficacy to learn statistics
(SELS) is defined as “confidence in one’s abilities to learn the skills necessary to solve specific tasks related to statistics” (p. 164).

Researchers have examined attempts to impact non-cognitive issues with the goal of improving statistics understanding based on the premise that challenges in statistics learning are related to affective issues such as anxiety, confidence, and motivation. McGrath, Ferns, Greiner, Wanamaker, and Brown (2015) used a mixed methods approach to examine the impact on statistics anxiety and performance of the implementation of various strategies for reducing anxiety as well as two specific alternative instructional strategies in a graduate level multivariate statistics class. Examples of the strategies aimed at reducing anxiety were the use of humorous cartoons, instructor interaction and availability, and non-traditional course assessments. The researchers found a significant reduction in statistics anxiety as measured by an abridged version of the STARS assessment. In addition, they found a significant increase in self-efficacy as measured by a modified CSSE. The original CSSE, which incorporated introductory statistics concepts, was updated to address topics relevant to the multivariate course that was the setting of the McGrath et al. study. The two alternative instructional strategies applied a collaborative, problem-solving approach to two particular course concepts. Although an experimental group within the class participated in these activities, the control group focused on the same course concepts by reading the textbook. Regarding the two alternative strategies, results indicated no significant difference between the experimental and control groups for anxiety measure or performance measures. However findings from semi-structured interviews conducted with the
participants suggest high feelings of satisfaction and low levels of stress related to the alternative learning activities. Therefore, the authors believed there is some value in these types of teaching activities. They attributed the lack of empirical evidence to small sample size, the time available to spend on the activities, and the choice of performance assessment.

Curran, Carlson, and Celotta (2013) studied the impact on attitudes of introductory statistics learners at the undergraduate level of implementing a collaborative learning community as an alternative learning strategy. The study found no significant differences between the learning community participants and the non-participants in either the pretest SATS assessment or the post assessment. However in looking at those students who had indicated initial negative attitudes regarding statistics, those attitudes were amplified over the course of the semester in the non-participant community whereas they remained relatively stable among the learning community participants. This suggests that an alternative instructional strategy implemented into the course may at a minimum hinder the development or deepening of negative attitudes towards statistics.

Taking a more general approach, Mvududu (2003) examined the relationship between constructivist learning environments and student attitudes toward statistics through a causal comparative study. The researcher examined the relationship between subscales from the Constructivist Environment Learning Survey (CLES) and the ATS scale to measure attitude toward statistics. The CLES is a validated instrument used to assess individuals’ perceptions of their learning environment. Results of the quantitative
model indicate that there is a significant relationship between constructivist characteristics in the classroom and students’ attitudes toward statistics.  

Research demonstrates the important role of non-cognitive factors in statistics learning and instruction. The majority of the studies that examine the relationship between affective considerations and performance have been empirical, quantitative studies. There are some studies that take a more phenomenological approach (see e.g., Griffith, Adams, Gu, Hart, & Nichols-Whitehead, 2012; McGrath, 2014; Pan & Tang, 2005). However, a key source for assessing these matters, the students themselves, is still largely ignored in the research. Indeed, an understanding of the essence of the experience of statistics instruction as perceived by the student is a needed addition to the literature.  

What is clear from these studies, however, is that non-cognitive factors greatly affect students’ abilities to learn and apply statistical reasoning skills (Gal & Ginsburg, 1994; Gal et al., 1997, Shaughnessy, 1992).

**Adult Learning of Mathematics and Statistics**

Adult learners of mathematics and statistics experience many of the same barriers to learning as do the general population of learners, such as misconceptions and difficulties in learning as well as affective issues including anxiety and self-efficacy. In addition, adult learners typically possess additional barriers, which Ritt (2008) classified as professional, institutional barriers, and personal barriers. Professional barriers pertain to the workplace and may include lack of tuition reimbursement and release time while institutional barriers involve access and affordability issues pertaining to higher education opportunities. Personal barriers may range from family commitments and scheduling
conflicts to prior negative experiences with schooling and a fear of returning to school (Ritt, 2008).

Jameson and Fusco (2014) examined these personal barriers as they pertained to mathematics learning of adults. The researchers administered the Abbreviated Math Anxiety Scale (AMAS) and the Mathematics Self-Efficacy Scale (MSES) surveys to both traditional and non-traditional learners. The results indicated that nontraditional learners scored significantly lower in math self-efficacy than did traditional students. Also, the researchers found several correlations between the constructs of math anxiety and math self-efficacy and characteristics of nontraditional learners. Specifically, there was a positive correlation between age and math anxiety and negative correlations between math self-efficacy and both age and the time lapse since the learner last took a math class. Jameson and Fusco also suggested that nontraditional learners’ confidence may be adversely affected by “younger, more recently educated, and more technologically savvy classmates” (p. 9). Jameson and Fusco recommended emphasizing learning goals over performance goals as a way to address the anxiety and self-efficacy issues of nontraditional learners.

Specific studies of active learning strategies with adult learners of mathematics have shown positive effects on both cognitive and non-cognitive factors. McDonald (2013) studied the effects of a researcher-developed active learning strategy called Step-by-Step Teaching in which learners proceed through a topic incrementally by showing understanding at each step before moving on. The strategy was introduced to adult learners enrolled in mathematics courses at a Caribbean university. The researcher
provided the steps for the students to follow and additional resources for learning the specific concept of inequalities, but then played a passive role in the classroom allowing the students to be active self-directed learners. The learners demonstrated positive outcomes regarding achievement and affective factors such as confidence and anxiety. Moreover, the participants self-reported positive changes in attitudes and confidence regarding mathematics. Hasan and Fraser (2015) conducted a mixed methods study of the effects of active teaching strategies, such as hands-on activities, games, realistic problem-solving, on adult learners’ perceptions of the classroom learning environment and their satisfaction with their mathematics learning opportunities. The study was conducted with adult males in the work Readiness Program (WRP) within the Higher Colleges of Technology (HCT) in the United Arab Emirates (UAE). A modified version of the College and Classroom Environment Inventory (CUCEI) was administered to the participants using five scales of the CUCEI. Personalization measures the perceived opportunities for participants to interact with the instructor and their perception of instructor concern for their welfare. Involvement gauges the degree to which students consider themselves to be active participants in the classroom environment. Satisfaction measures the overall enjoyment of the class. Task orientation is indicative of the perceived organization and clarity of the class activities. Individualization measures the extent of the student’s perceived autonomy and consideration of their abilities and interests. The results indicated significant effects for each of the five scales. The qualitative results of the study supported these results with participants expressing satisfaction with the hand-on, self-directed, and collaborative aspects of the class.
environment. In addition, participants reported increased satisfaction with mathematics learning and positive changes in perceptions they held about the difficulties of learning mathematics based on prior experiences.

Much of the research in statistics education concerns the undergraduate population of learners, which encompasses both traditional and nontraditional learners. There is limited research in statistics education focused solely on adult learners. S. Porter (2005) detailed her experiences with teaching statistical concepts to adult learners enrolled in a Sampling and Surveying course of a two year Diploma in Marine Studies program. Her recommendations included limiting the mathematics involved in presenting statistical concepts, using real-life problems, and allowing the learners to direct their learning through their choice of applications and problem-solving approaches. Forbes (2014) undertook an action research study to develop a course in statistical literacy for adult learners. Her findings suggested that the implementation of active hands-on learning activities and an emphasis on conceptual understanding of statistical techniques over their mathematical underpinnings positively affected both cognitive and non-cognitive factors.

Ross-Gordon’s (2011) review of the literature on adult learner in college classrooms confirms “adult students’ preferences for active learning strategies that support cognitive growth and transformational learning, along with their desires for immediate application of knowledge and opportunities for self-direction” (p. 29). However, her review also demonstrates the extensive influence of non-cognitive issues of
adult learners such as confidence and perceptions resulting from previous educational experiences.

Attention to the characteristics, preferences, and challenges of adult learners is necessary for my study because of the setting of the adult learning program. However, nearly half of the participants enrolled in the specific section of the course that was the setting of this study were classified as traditional students. Applying Knowles’ principles of adult learners and findings from research based on these principles could be considered problematic in this mixed learner setting if the theory of andragogy is strictly interpreted as the theory of teaching adult learners as it was initially defined by Knowles (Conner, 1997-2004). However, the use of the term andragogy has evolved toward a view of learner-centered education. In this view pedagogy and andragogy are seen as ends of the continuum ranging from teacher-directed to student-directed learning. Andragogy is “concerned with providing procedures and resources for helping learners acquire information and skills” (Holmes & Abington-Cooper, 2000, Pedagogical and Andragogical Models, para. 11) as contrasted with the pedagogical model of direct transmission of information and skills. In this perspective, the recommendations for learning environments and strategies based on adult learning principles may be beneficial for all learners.

**Concept Mapping**

Concept mapping has enjoyed prominence in science education since its origin in that field over 40 years ago. Over the last few decades it has gained attention in mathematics education and statistics education. A common use of concept mapping
remains assessment. However, in the last three decades, concept mapping has gained momentum as an effective tool for instruction and learning.

**Concept Maps in Assessment**

Research studies involving concept maps for assessment typically examine their validity and effectiveness for assessing content knowledge and/or implement concept maps as assessment tools to gauge understanding or changes in understanding as a result of a specific intervention or instructional strategy. Wilcox (1998) described the use of concept mapping as part of an extensive collaboration between classroom teachers, mathematicians, teacher educators, and graduate student researchers to improve assessment techniques and better align them with the vision of the National Council of Teachers of Mathematics (NCTM) Standards. Wilcox described how these parties reached better consensus about what topics, ideas, and connections are important to address in a classroom setting by constructing, collaborating on, and discussing concept maps. In addition, Wilcox presented an example of how a middle school mathematics teacher used student constructed concept maps to track knowledge growth over time. The benefits of the use of concept mapping in this setting include the advantage of an additional assessment tool as well as encouraging student reflection and communication and imparting a sense of empowerment to the students based on their observed growth reflected in their concept maps.

Hasemann and Mansfield (1995) presented the results of two studies examining the ability of concept mapping activities to track changes in understanding over time for elementary and middle school students. Both studies focused on specific mathematical
areas, fractions and geometry, respectively. Also, in both studies, students constructed concept maps by arranging and linking given concept names at various time intervals over the course of instruction on the topics. Results suggest that concept maps can illustrate growth in understanding, illuminate how students connect and organize concepts, and identify misconceptions and difficulties in understanding. Like, Hasemann and Mansfield, Merrill (1987) examined the use of concept maps to assess understanding of a particular topic: division. Preservice teachers were given training in concept mapping and then were asked to map their understanding of division. Results confirm the validity of concept maps scores as an indicator of mathematics performance. Williams (1998) also examined the validity of concept maps as a way to assess conceptual knowledge of a specific concept: function. The author examined concept maps constructed by experts (PhD mathematicians) as well as college level students enrolled in traditional and reform Calculus classes. Assessment of the maps indicated little variance among expert-constructed maps and significant variance between expert and student maps. Further results suggest discernable differences between the two student groups as well. The author believed these results suggest that the use of concept maps is valid for assessing conceptual knowledge, even detecting subtle differences in levels of understanding. Wholeben’s (1994) quantitative study using concept maps to assess daily changes in teachers’ understanding of fractals, chaos, and dynamics in a five-day professional development workshop and Grunow’s (1998) mixed-design study using concept maps to assess teachers’ growth in understanding of rational numbers over the
course of a two-week professional development course also confirmed that concept maps are a valid instrument for the assessment of content knowledge and conceptual change.

**Concept Maps as Learning Tools**

Numerous research studies examine the use of concept maps as instructional and learning tools, including several meta-analyses, over a broad range of subject areas (include citations here, even those not fleshed out later). In Schwendimann’s (2015) review of the literature on concept mapping in education, he noted the use of concept mapping as a learning tool as a major focus of the research. In addition, he found consensus on the effectiveness of concept maps for increasing knowledge integration and meaningful learning across disciplines and ages of concept map users. Horton et al. (1993) presented the results of a meta-analysis that examined the effectiveness of concept mapping for improving performance as well as student attitudes in primarily science content areas. Results suggested an improvement in both performance and attitudes achieved from the use of concept maps as an instructional tool. In addition, the authors found no significant difference in performance based on whether the concept maps used in instruction were teacher- or student-prepared. Nesbit and Adesope (2006) performed a more comprehensive meta-analysis that examined a broader range of content areas as well as more specific research questions. Their research suggests both constructing concept maps and viewing preconstructed maps improves knowledge retention over a broad range of subjects.

Specific studies include Schmid and Telaro (1990) who examined the effectiveness of concept mapping as an instructional tool in high school biology. Their
experimental design concluded that concept mapping directionally improved performance for all learners in the study, and significantly so for students classified as lower-ability students. Weinholtz (1995) conducted a case study examining the effectiveness of concept mapping as an instructional and assessment tool for a preservice integrated methods course. Results confirmed that concept mapping helps students engage in more meaningful learning, better organize ideas, and identify their misconceptions and lack of understanding. The process also helps impacts meta-cognition and communication of ideas and understandings. Chiou (2008) examined the use of concept mapping as a learning tool for advanced accounting. An experimental design revealed significantly higher achievement for the student group that incorporated concept mapping in their learning process. Furthermore, a Likert scale questionnaire administered to the concept-mapping group revealed positive attitudes about and satisfaction with the use of concept mapping as a learning tool. Jones, Ruff, Snyder, Petrich, and Koonce (2012) also explored the affective implications related to a mapping tool. The authors examined the impact of mind mapping activities on motivation. Although there are differences between concept mapping and mind mapping, both techniques are recognized for being effective graphical tools for organizing and representing knowledge. As part of their analysis, the researchers determined that 62% of the participants appreciated the usefulness of the maps and the feeling of empowerment gained from creating them.

Studies focused in the field of mathematics include Afamasaga-Fuata’i (2009); Bartels (1995); Baroody and Bartels (2000); Poling, Goodson-Espy, Dean, Lynch-Davis, and Quickenton (2015); Swarthout (2001); and Vagliardo (2006). Afamasaga-Fuata’i’s
teaching experiment utilizes student-created progressive concept maps to explore the participants’ emerging knowledge of advanced mathematics concepts. The experiment illuminates three key phenomena observed regarding this use of concept maps. First, the iterative creation of concept maps throughout the experiment has contributed to more complex and detailed concept maps revealing more meaningfully integrated concepts. Second, the author notes that the concept maps were enriched via social interactions including group presentations, peer critiques and one-on-one consultations with the instructor. Third, the metacognitive effect of concept mapping is illustrated through the participants’ recognition that the creation of concept maps necessitates a deep understanding of the connections between concepts in addition to basic knowledge of the concepts. Bartels has conducted a qualitative study of preservice teachers’ understanding of five topics in an elementary methods course. Students have constructed concept maps; student discussions and written assignments have been analyzed. Findings suggest that concept mapping is an effective instructional tool for promoting mathematical connections and improving understanding. Baroody and Bartels (2000) recommended the use of concept maps as a learning tool for middle school mathematics. They offered suggestions for teacher-created concept maps as well as discussing the effectiveness and benefits of student-created concept maps. Poling et al. (2015) provided an example of a learning strategy for pre-service teachers that combines iterative concept mapping with content analysis. Key benefits the authors noted in the use of concept mapping are the ability to organize knowledge, enrich connections between concepts, and illuminate gaps in knowledge, all prevalent challenge in statistics understanding. Like Afamasaga-Fuata’i
(2006), Poling et al. (2015) promoted the use of iterative concept maps as a way to increase the sophistication of both the concepts and their relationships in the learners’ knowledge structure. Swarthout (2001) has undertaken quantitative analysis to examine the effect of concept mapping as an instructional tool on the mathematical achievement, attitudes, confidence, and beliefs of preservice teachers. Vagliardo (2006) proposed the use of concept mapping combined with another instructional strategy, historical research, as a way to encourage more meaningful understanding of the mathematical concept of logarithm.

**Concept Mapping in Statistics Education**

Concept mapping research in statistics education mostly follows the paths of concept mapping research in mathematics and other areas, which are studies focused on concept maps as an assessment tool and investigations of concept mapping as an instructional and/or learning tool.

Many of the concept mapping studies in the area of statistics education examine the effectiveness and validity of the use of concept maps for assessment. Michael’s (1994) study investigated the validity and reliability of concept maps for assessment in graduate level statistics and measurement courses. Correlations between concept map scores and achievement test scores supported the validity of concept maps as an assessment tool and an examination of student concept maps over time supported the reliability of the measure as well. Roberts (1999) investigated the validity of concept maps as a pre- and post-test assessment of cognitive outcomes regarding topics in statistical inference. A significant relationship between concept map scores and
assignment scores were found. Furthermore, a qualitative assessment of the concept maps suggests that some information, such as misconceptions, not visible through traditional assessment methods may be revealed through assessment of the concept maps. Lavigne (2005) undertook a case study approach to investigate the effectiveness of concepts maps as a tool for assessing knowledge representation. The particular subject area studied was inferential tests commonly introduced in introductory statistics courses. Results suggest that concept maps are appropriate for assessing overall content knowledge. Lavigne et al. (2008) presented the results of a case study analysis that investigated mental representations of inferential statistical tests. The authors were interested in the students’ ability to categorize word problems by the appropriate inferential test needed to solve them based on certain characteristics such as purpose of test, type of data, and type of variables. In addition, the students constructed concept maps demonstrating their knowledge of these concepts and their interrelatedness. Qualitative assessment of the concept maps suggests the students have difficulty integrating and connecting the concepts, which may cause the difficulty in the sorting task. In Yin’s (2012) study, the researcher confirmed validity and reliability of tree diagrams as an assessment tool for introductory statistics. As tree diagrams and concept maps both belong to the class of graphical organizers used to structure and represent knowledge, the study further informs the effectiveness of concept mapping as a tool for assessing knowledge structures in statistics. Concept maps differ from tree diagrams mainly in their use of cross links and propositions, that is, labeling of the links. In the analysis, Yin contended that tree diagrams are indeed useful for quick assessment of
student understanding. However, the author conceded that concept maps are more appropriate for assessing students’ deep thinking and understanding of complex relationships.

In the last two decades, some studies have begun to explore concept mapping as an instructional/learning tool for statistics. Bulmer (2002) developed an interactive concept map accompanied by a narrative to explain the overarching ideas of the introductory statistics course. Also, Icaza, Bravo, Guinez, and Munoz (2006) developed a web-based concept map used as a supplement to other learning materials provided to introductory statistics students. Luchini, D’Argenzio, and Moncecchi (2002) examined the change in understanding of basic statistics and data analysis concepts of elementary school students throughout the school year through the use of both teacher and student constructed concept maps. Doorn and O’Brien (2007) performed an experimental design with the treatment group receiving an additional instructional strategy of concept mapping in an introductory statistics course. Analysis of post-test differences showed no significant difference between the two groups. However, the authors noted factors such as the small amount of time spent on learning concept mapping and students’ pre-existing beliefs about learning strategies may be confounding the results. Chiou (2009) performed a quantitative study examining the effects of collaborative concept mapping, individual concept mapping, and traditional textbook exercises on performance in a business and economics statistics class. Results showed significant improvement in achievement due to concept mapping, particularly collaborative concept mapping. Izumi (2013) documented the results of a workshop focused on data analysis with particular
examination of understanding of measures of center with the participants representing their learning process through concept maps at the beginning and end of each meeting. Through this study, Izumi has noted an increase in meta-cognitive learning and self-regulatory processes as well as deeper conceptual understanding through active cognitive construction. Cravalho (2010) constructed an experimental design to test the effect of concept mapping on statistics anxiety and academic performance. The treatment group received concept map training and completed concept map worksheets and student-created concept maps throughout the semester. Both the control group and the treatment group completed the STARS survey to measure anxiety and instructor-created exams to measure academic performance. The results indicated no significant effect of concept mapping on academic performance or overall statistics anxiety. However, the researcher did find a significant difference between the two groups on the STARS subscale of Interpretation which suggests that the concept mapping group felt less anxious about interpreting statistical results at the end of the term. Although, this reduction in anxiety did not translate into improved academic performance as the researcher expected, the researcher still suggested that the decreased interpretation anxiety may indicate that students are more confident in their conceptual understanding of the subject as the result of the concept mapping activities.

In summary, the research shows that concept mapping has been a commonly used tool since its inception. Although its use remains largely in the domain of science and for assessment, there is a growing emphasis on its effectiveness as a learning tool across disciplines. Specifically, the use of concept mapping as a learning tool in statistics
education, while still not as pronounced as in other areas, is widely believed to hold great potential for addressing the difficulties in statistics learning. The challenges that concept mapping in statistics has been shown to address include the need to develop deeper conceptual understandings, the necessity to better relate ideas and concepts, the development of increasingly sophisticated knowledge integration structures over time, the ability to reason statistically, and the influencing of affective factors.

**Summary**

This chapter summarized key research in statistics learning, adult learning in mathematics and statistics, the role of affect in learning statistics, and the use of concept mapping.

The research in statistics education continues to show pervasive challenges for statistics learners including misconceptions, difficulties in relating concepts to each other, the need for general statistical reasoning ability, and affective hurdles. Statistics education initiatives have demonstrated a shift toward the focus on development of statistical reasoning and conceptual understanding. This focus is represented through the implementation and examination of active learning strategies that focus on both cognitive and social construction of knowledge.

The literature focusing on the adult learning of mathematics and statistics primarily focuses on the effectiveness of active, self-directed learning approaches and an attention to the non-cognitive factors influencing adult learning.

The research has illuminated the strong link between non-cognitive factors and cognitive outcomes. This link calls for continued exploration into engaging and
impacting non-cognitive factors in introductory statistics education. The research suggests that learning strategies that effect anxiety and attitudes toward statistics, particularly notions of perceived competence and self-efficacy, should be investigated. Much of this research has assessed these affective factors quantitatively; a more phenomenological approach is warranted.

Although concept mapping for assessment still predominates in the literature, attention to concept mapping as a learning tool has emerged recently. The research on concept mapping demonstrates that concept maps are effective learning tools that foster deeper conceptual understanding by allowing for the creation of sophisticated relationships between concepts. Concept mapping also is a valuable metacognitive tool in that it helps students to self-regulate their own learning by identifying their own misconceptions and faults in reasoning.

Statistics education is still not strongly represented in the literature on concept mapping and much of that research is related to concept mapping for assessment and evaluative purposes. The examination of concept mapping as a learning tool in statistics has not been widely examined in the literature and not from a deeply phenomenological approach. In addition, the metacognitive benefits of concept mapping that have been well documented in other subject areas have not been addressed widely with regards to learning of introductory statistics concepts. The review of the literature has provided the reader with the background that framed this study.
CHAPTER III

METHODOLOGY

This chapter describes the selection of the chosen methodology for this study including rationale for the choice. Also, the chapter includes the details of the study design, including setting, participants, data collection, and data analysis. It concludes with the description of a pilot study that informed the direction of the current study.

Theory of the Method (Design) and Procedures

As a whole, statistics education research may be considered an interdisciplinary field of research (Shaughnessy, 1992; Zieffler et al., 2008) due to the nature of the subject of statistics, the variety of departments housing postsecondary statistics courses, and the diversity of the researchers. The origins of the field of statistics are wide and diverse (Hald, 1998, 2003; Moore & McCabe, 2006; Stigler, 1986). This diversity in origin continues into the interdisciplinary nature and broad application of the field today. Introductory statistics courses are commonly offered by a wide variety of academic departments, including statistics, mathematics, psychology, education, sociology, economics, and business, whose members have contributed to the field of statistics education research. Indeed, according to Zieffler et al. (2008, Section 1), “because of the diversity in backgrounds of researchers (e.g., psychology, educational psychology, statistics, statistics education, and mathematics education), scholarship related to the teaching and learning of statistics has appeared in journals from many disciplines.” Because of this, “statistics education research has not relied on any one tradition of empirical research methodology” (Section 1). Shaughnessy (1992, p. 465), too, noted
“the cross fertilization of research traditions and methodologies in probability and statistics.”

The Research Advisory Board of the *Consortium for the Advancement of Undergraduate Statistics Education* (CAUSE) defines statistics education research in the following way:

Statistics education research focuses on both the instruction and learning of statistics at all levels, using any appropriate research methodology (qualitative and quantitative) that addresses the question being asked . . . The research methodology should follow from the research question (and not the other way around). (Research Advisory Board of the Consortium for the Advancement of Undergraduate Statistics Education)

In letting my research questions guide me in my choice of methodology, I felt that my focus and goals were calling me to be a qualitative researcher. Bogdan and Biklen (2003) described qualitative researchers as those who “are concerned with understanding behavior from the subjects’ own frame of reference . . . [and] collect their data through sustained contact with people in settings where subjects normally spend their time” (p. 2). Within the naturalistic setting of the classroom, I wanted to understand and describe how the students experienced the learning of introductory statistical concepts through the use of concept mapping and how concept mapping informed their perceptions of their learning and knowledge. Given this was the first time I had used concept mapping in my course, I had no specific hypotheses or conjectures in mind to test about these phenomena. Upon reflection, I felt that these goals for my research were closely aligned
with Bogdan and Biklen’s (2003) five characteristics of qualitative research: (a) qualitative research is naturalistic, that is, it takes place in an actual setting with the researcher as a key instrument; (b) the data are descriptive, words and illustrations rather than numbers; (c) the research is process-focused, not concerned solely with outcomes and gauging some measure of their effectiveness; (d) data are analyzed inductively, that is, there are no specific hypotheses to test; and (e) the research is focused on meaning, or participant perspective.

Practically speaking, I hoped that the findings would inform my teaching and be of use to other instructors of introductory statistics. For all of these reasons, I chose a qualitative approach for my study; specifically, I selected the methodology of the case study.

**Case Study Methodology**

Merriam (1998, p. xiii) defined a qualitative case study as “an intensive, holistic description and analysis of a bounded phenomenon such as a program, an institution, a person, a process, or a social unit.” For this study, the bounded system was the process of implementing concept mapping into the introductory statistics course. Since I aimed through my research questions to characterize how students experienced learning through the use of concept mapping and how they perceived the impact of concept mapping on their learning, my study necessitated a methodology that would provide the intensive, holistic description of the case as espoused by Merriam. Furthermore, Yin (1994) characterized the case study approach as advantageous for answering how and why questions.
Creswell (1998) further described case studies as investigations “through detailed in-depth data collection involving multiple sources of information rich in context” (p. 61). As part of my course design for my initial implementation of concept mapping, I planned to collect concept maps created by the students and other student work samples. Also, I developed a questionnaire to gain feedback from the students regarding this implementation. Therefore, these documents would be readily available for analysis. These documents, then, as well as direct observations and interviews combined to provide an array of information resulting in a description of greater depth and richness.

Stake (1995) categorized case studies as intrinsic, instrumental, and collective. In an intrinsic study, the unique case itself is the subject of interest. An instrumental study uses the case as an “instrument” to study a particular issue. Finally, a collective case study involves more than one case. For my study, I felt that an instrumental case study was appropriate because I was focused on a single case setting. In addition, my goal was not intrinsic to this case, that is, I was not focused solely on understanding this particular case. Rather, I sought to gain insight into an issue, specifically, the impact of an implementation of an alternative learning strategy into an introductory statistics course.

As with any research study, I was concerned with questions of validity. In qualitative research, internal validity has been equated with how well the analysis and resulting narrative represent the actual happenings of the case and the participants’ meanings. The triangulation of data possible because of the multiple data sources in a case study served to increase the trustworthiness of my representation of the case findings. External validity has been represented by the transferability of the research to
other settings or cases. My selection of instrumental case study methodology was consistent with this objective as instrumental case studies “may allow for the generalisation of findings to a bigger population” (Zainal, 2007, p. 4).

There were other characteristics of the case study approach that were well aligned with my research focus and setting of interest. First, one of the hallmarks of case study research is the real-world context of the case (Yin, 1984). That is, the data are collected within the environment of the participants thus leading to a deeply contextual description. Also, considering that the setting was the relatively small class in which I had planned to implement concept mapping as a learning tool, I did not have a large sample. When large samples are not feasible, case studies are particularly appropriate because the depth of the information available. Finally, since the case involved the initial implementation of this learning strategy in my course, the analysis integral to a case study approach helped me adapt initial ideas I had about the process and illuminate novel hypotheses for future research.

Additionally, a goal of this study was to craft a description that reflects the perspectives of the participants, and according to Merriam (1998), the case study approach is the appropriate choice when the goal is to “gain an in-depth understanding of the situation and meaning for those involved” (p. 19). Indeed, Stake (1995) contended that the case study allows for a “‘thick description,’ the interpretations of the people most knowledgeable about the case” (p. 102).
Design/Plan of the Study

In order to achieve an in-depth analysis of the issue of the impact of concept mapping on student experiences, careful consideration had to be given to both the context of the case and the procedures for data collection. This section details the setting, participants, and data collection tools and processes that comprise the case study.

Setting

This case study was undertaken in my introductory statistics course during the Spring Semester of 2012. The setting for the case study was a small, selective Midwestern liberal arts college with a traditional undergraduate enrollment of about 1,200 students and an additional 300 students enrolled in The Weekend College (WEC), an alternative program designed to offer the college’s traditional undergraduate curriculum to adult learners. This alternative program offered 8 majors culminating in a Bachelor of Arts degree, and the median age of its students was 38. The specific class setting for the case study was a freshman level undergraduate introductory statistics course offered in the WEC program. This class met in the Spring semester with seven 4-hour sessions on alternating weekends over a 12-week term. The design of the course was inquiry-based with class sessions a mixture of lecture, discussion, collaborative problem-solving, technology demonstration, and hands-on technology sessions. Also, to aid in continuity between the widely spread class sessions, an online course management tool was used that provided a repository for course documents and assignments; a chat room and dedicated email system for class members; and links to online resources for additional help, supplementary information, computer learning tools, and statistical
analysis software. The course syllabus, outlining general policies and expectations as well as a topics schedule, was posted to the online course management system a week before the beginning of the term (see Appendix A).

Participants

This study involved a convenience sample taken from my introductory statistics course. The specific demographics of the class for this case study were unknown until the beginning of the data collection as course registration is permitted up to the beginning of classes each semester. Historically, there had been somewhere between 12 to 20 students in the WEC introductory statistics class with varying class standing and mathematics preparation. Typical WEC classes had been comprised mainly of adult learners, but having a few traditional undergraduates had not been uncommon. The Spring 2012 class, during which this study was performed, was comprised of 14 students, 3 of whom held junior standing and 11 of whom were graduating seniors. The class consisted of 8 females and 6 males. Although the class was considered a freshman level course, the class was comprised solely of upperclassmen. In addition, seven of the students were enrolled as WEC students and seven were “traditional students,” that is, students enrolled in the traditional undergraduate program of the college. Although it was somewhat unusual to have this high a percentage of traditional students enrolled in the Weekend College class, it was not unexpected for this particular class. The introductory statistics course at this institution generally has been in high demand due to the course being a requirement for several majors as well as a serving as an elective course meeting a “core curriculum” designation. Furthermore, due to staffing, budget,
and other administrative constraints, demand for the course has tended to outpace the number of offerings of this course on the class schedule. Since this course was offered in the spring, there were many graduating seniors, both in the traditional college and the Weekend College, who required this course for graduation at the end of the semester. These reasons contributed to the larger percentage of traditional students in the class and to the fact that all the class members had upper-level standing.

A letter explaining the intended research and asking for volunteers to serve as research participants was distributed and explained at the first class session of the semester. The students had already been introduced to the topic of concept maps and their intended use in the course via their initial assignment for the class. There were two levels of participation for the research participants in my study: Study Participants and Key Informants. Twelve of the 14 students enrolled in the class elected to be research participants.

*Study participants* consented to certain documents, including their concept maps, homework assignments, exams, and a questionnaire, being analyzed for purposes of this study. As a study participant, there was no additional time requirement beyond the time that would normally be invested in the course. Of the 12 students who agreed to participate in the study, four students elected to join at the study participant level.

*Key informants* consented to the same as that of the study participants as well as to other sources of data collection that served the phenomenological aspect of the case study. Key informants maintained and provided to the researcher a journal documenting their experiences with concept mapping throughout the course. In addition, key
informants participated in one-on-one audio-taped interviews with the researcher regarding these experiences. Based on historical enrollment figures for the course and the fact that most students enrolled in Weekend College courses are busy adults with work, family, and other school obligations, it was anticipated during the initial design of the study that between two and four students might choose to participate as key informants. Ultimately, eight of 12 students agreeing to participate in the study also elected to be key informants. However, not all key informants were able to fulfill each of the requested tasks.

I decided not to do any prescreening to determine who I would invite to be the study participants or the key informants of my study; rather I recruited on a purely volunteer basis. I did this for several reasons. I wanted to inform the experience of the initial implementation of concept mapping in my class; I desired this to be as authentic as possible and to obtain as varied a perspective as possible. I did not want to exclude potential participants based on any criteria such as previous experiences with mathematics, statistics, and concept mapping or self-reported study habits and preconceptions about the course. Nor did I want to exclude participants based on my perceived commitment of their ability to complete the various forms of evidence to be analyzed in the study. The demographic information for those who elected to participate in the study has been compiled in Table 1.
Table 1

Demographic Information of Study Subjects

<table>
<thead>
<tr>
<th></th>
<th>Enrolled Program</th>
<th>Class Standing</th>
<th>Gender</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>WEC</td>
<td>Traditional</td>
<td>Junior</td>
</tr>
<tr>
<td>Study Participants</td>
<td>2</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Key Informants</td>
<td>5</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>All Subjects</td>
<td>7</td>
<td>5</td>
<td>3</td>
</tr>
</tbody>
</table>

Procedures

The goal of the study was to document the experience and impact of implementing concept mapping as a supplemental learning strategy in an introductory statistics course. Data were collected throughout the duration of the semester-long course, and included observations, audio-taped interviews, documents, a questionnaire, and journals. All information related to the experience and impact of the concept mapping procedure was collected in the manners detailed in the Data Sources section.

All enrolled students completed concept maps for each unit of study as part of the course requirements. Specifically, after each class session, each student constructed a concept map pertaining to the topics discussed in that session, including previously discussed concepts as appropriate. Table 2 presents a summary of all concept map assignments for the term and their associated topics. Each subsequent class session began with a discussion of the concept maps. Finally, at the end of the semester, each student was asked to create a single concept map that incorporated and integrated the
individual’s previous concept maps. All discussions and assignments involving the 
concept maps were required for all students enrolled in the course regardless of their 
decision to participate in the research study. However, only those who were research 
participants had their concept map data included in the study.

Table 2

*Description of Concept Map Assignments*

<table>
<thead>
<tr>
<th>Concept Map Assignment</th>
<th>Concept Map Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>CM 1.1</td>
<td>The Game of Basketball</td>
</tr>
<tr>
<td>CM 1.2</td>
<td>Student’s choice of personal interest</td>
</tr>
<tr>
<td>CM 2</td>
<td>Topics from Week 1 class: overview of statistics, basic terms</td>
</tr>
<tr>
<td>CM 3</td>
<td>Topics from Week 2 class: descriptive statistical measures</td>
</tr>
<tr>
<td>CM 4</td>
<td>Topics from Week 3 class: bivariate data, random variables and probability distributions</td>
</tr>
<tr>
<td>CM 5</td>
<td>Topics from Week 4 class: normal probability distribution</td>
</tr>
<tr>
<td>CM 6</td>
<td>Topics from Week 5 class: sampling distributions, overview of inference</td>
</tr>
<tr>
<td>CM 7</td>
<td>Integrated map or maps of topics from entire term</td>
</tr>
</tbody>
</table>

The researcher chose to focus the study on student-created concept maps as 
opposed to teacher- or expert-created concept maps. The intent of the study was to 
investigate the effects of concept mapping as a learning tool, specifically, when the maps 
were created by the learners for organizing their own knowledge. Student-created concept 
maps were consistent with the constructivist view that knowledge is individually 
constructed and that construction is heavily dependent on the individual connecting new 
concepts with existing knowledge. Furthermore, Baroody and Bartels (2000) contended
that having students create their own concept maps was “consistent with the inquiry-based approach envisioned by the National Council of Teachers of Mathematics” (p. 606).

Training in concept mapping was provided in written form as part of the initial assignment that was distributed to students prior to the beginning of the semester. Students in the Weekend College were accustomed to completing substantive initial assignments and reading prior to the beginning of their courses, so this was not viewed as a hardship. In addition, a brief in-person tutorial and discussion of concept mapping took place at the first class meeting. Training on the use and construction of concept maps prior to the onset of the study was consistent with the literature (Chiou, 2008, 2009; Doorn & O’Brien, 2007; Hough & Weissglass, 2006; Lavigne, 2005; Lavigne et al., 2008; Liu et al., 2009; Roberts, 1999; Weinholdt, 1995; Williams, 1998), and the training protocol was developed based on the recommendations of Novak and Gowin (1984).

**Data Sources**

Creswell explained, “a case study involves the widest array of data collection as the researcher attempts to build an in-depth picture of the case” (1998, p. 123). In order to achieve this detailed depiction and to ensure triangulation of data necessary for the credibility and validity of the study, various data sources were used. Furthermore, data was collected with explicit permission from all participants and in accordance with Institutional Review Board (IRB) guidelines. The various articles of data collection are described in more detail in the following sections.
Reflective Journal

Researcher journals are used commonly in qualitative research as a means for the researcher to reflect upon the research process, including the role of the researcher in the process. “The notion of a comprehensive reflective journal to address the researcher’s Self is critical in qualitative work due to the fact that the researcher is the research instrument” (Janesick, 1999, p. 506). I maintained a reflective journal to document my experiences of preparing to implement concept mapping as an additional instructional strategy as well as reflections on experiences during the class sessions. Field notes and observations were included in this journal as well. Field notes, observations, and reflections were documented after each class session in the journal to help interpret individual reactions and group interactions. These data were used to guide and inform the next class activities as well as to add to the body of information for data analysis in order to enhance the triangulation of the data.

Key Informant Interviews

Interviews were deemed to be an important part of the data collection due to the role of affect in the study. Perceptions about individual experiences and attitudes may be more demonstrable in an interview setting than through observations or documents. I chose to conduct semi-structured interviews. Semi-structured interviews include preset questions but also may address questions that arise during the interview (Mills, Durepos, & Wiebe, 2010). Therefore, I followed a script with preset open-ended questions. However, additional questions were asked in order to clarify statements made by the subject or if the subject’s response triggered a different line of questioning. I chose this
type of interview because of the perceived benefits of this type of interviewing. According to Cohen and Crabtree (2006), semi-structured interviews allow the interviewer to feel prepared and they allow participants the ability to freely convey their individual views while still providing comparable data.

I completed the initial interviews before the third week of the semester and a final interview at the close of the semester after final grades were posted. Each interview was a private one-on-one interview between the researcher and the participant, and the interviews were tape recorded and transcribed. Interview scripts are included in Appendix B. The initial interview was a brief meeting to obtain a baseline perspective relative to the issues addressed in the research questions. Seven of the eight key informants participated in the initial interview. In the final interview, I asked more specific questions to gather information about the key informant’s experience of using concept mapping throughout the semester as well about the perceived impact of concept mapping on the ability to relate and apply statistical concepts. Only one of the eight key informants participated in a tape-recorded final interview. The others relayed their information through their final journal entry, the questionnaire, and informal interviews with the researcher.

**Key Informant Journals**

The key informants were requested to keep a journal throughout the semester where they were asked to record their experiences and feelings about implementing concept mapping, including learning to use the tool, how it impacted their existing learning and study strategies, and how they felt it has impacted their comfort with and
their ability to relate and apply the statistical techniques and concepts introduced throughout the semester. The key informants were asked to complete journal entries after each of the class sessions beginning at week 2. Journal prompts provided direction for their writing in order to guide them to address the topics listed above. With the exception of the first and last journal entries, the prompts remained the same so that the subjects could document their evolving feelings and perceptions regarding their use of concept mapping. The journal prompts are included in Appendix C. Three key informants provided me with their journals.

**Questionnaire**

All research participants were asked to complete a brief questionnaire at the last class session regarding their experiences with using concept mapping in the course. The questionnaire, included in Appendix D, was designed to elicit more specific and focused responses than may possibly have been provided during the class discussions. In addition, the completed questionnaires provided an additional source for triangulation. The questionnaires were permitted to be completed anonymously. The researcher felt that this gave the respondents the freedom to be more forthcoming with their feelings and experiences regarding concept mapping. All 12 subjects completed the questionnaire.

**Documents**

Merriam (1998, p. 112) defined documents generally as “a wide range of written, visual, and physical material relevant to the study at hand.” This case study made use of what Merriam referred to as researcher-generated documents; that is, documents “prepared by the researcher or for the researcher by participants after the study has
begun” (p. 119). In addition to the researcher and key informant journals, student concept maps generated throughout the semester as well as other assignments and tests were examined. Although the completion of concept maps, assignments, and exams was a requirement for all students enrolled in the course, only those students consenting to participate in the study had their documents analyzed for purposes of this case study.

**Data Collection Procedures**

In this section, I describe how I collected and maintained evidence pertaining to the various data sources described in the previous section. Table 3 summarizes a schedule of research activities aligned with the topics of each class session.

I began my reflective journal prior to the beginning of the term. As this was the first time I had implemented concept mapping into my course, I wanted to document my preparation, expectations, and concerns for the implementation. I wanted to document my expectations before the beginning of the term to help illuminate any biases or preconceived notions I may have brought to the study. Throughout each class session, I attempted as best I could to keep field notes, which I incorporated into my reflective journal. During the class discussions of concept mapping, I jotted down quick notes of the key statements of the discussion participants. At the first break, I filled in those notes in greater detail and asked individuals for clarification if necessary. Then at the end of each class session before leaving campus, I rewrote those notes and incorporated other observations from the remaining class session and any informal conversations I had with participants during breaks or after class. Later in the day of each class session, I began my reflective journal entry pertaining to that class session and incorporated the field
<table>
<thead>
<tr>
<th>Week</th>
<th>Lesson Plan</th>
<th>Research Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Overview of course policies; review of technology resources; review of concept mapping; discussion of sampling and univariate graphical descriptive measures; completion of light-hearted demographic class survey used later in term for data analysis exercise</td>
<td>Reviewed constructing concept maps based on previously distributed tutorial; shared CM 1.1 and 1.2 concept maps; field notes; researcher journal</td>
</tr>
<tr>
<td>2</td>
<td>Discussion of univariate numerical descriptive measures; demonstrations of use of Excel and calculators for producing graphical and numerical descriptive measures; small group problem-solving session</td>
<td>Provided written feedback on CM 1.1 and 1.2 concept maps; shared CM 2 concept maps and discussed experiences with concept mapping; field notes; researcher journal; key informants completed journal entries; audio-taped interviews with key informants</td>
</tr>
<tr>
<td>3</td>
<td>Discussion of bivariate descriptive statistics and properties and applications of random variables and probability distributions for discrete data; whole-group problem-solving session</td>
<td>Provided written feedback on CM 2 concept maps; shared CM 3 concept maps and discussed experiences with concept mapping; field notes; researcher journal; key informants completed journal entries</td>
</tr>
<tr>
<td>4</td>
<td>Completion of mid-term exam; discussion of properties and applications of random variables and probability distributions for continuous data with particular emphasis on the normal distribution, small-group problem-solving session</td>
<td>Provided written feedback on CM 3 concept maps; shared CM 4 concept maps and discussed experiences with concept mapping; field notes; researcher journal; key informants completed journal entries</td>
</tr>
<tr>
<td>5</td>
<td>Review of graded mid-terms; discussion of theory and applications of sampling distributions and the Central Limit Theorem for the mean; discussion of point and interval estimates; whole-group problem-solving session</td>
<td>Provided written feedback on CM 4 concept maps; shared CM 5 concept maps and discussed experiences with concept mapping; field notes; researcher journal; key informants completed journal entries</td>
</tr>
<tr>
<td>6</td>
<td>Discussion of parametric inferential techniques for hypothesis testing; whole-group problem-solving session</td>
<td>Provided written feedback on CM 5 concept maps; shared CM 6 concept maps and discussed experiences with concept mapping; field notes; researcher journal; key informants completed journal entries</td>
</tr>
</tbody>
</table>

*Table continues*
Table 3 (continued)

Schedule of Weekly Topics and Research Activities

<table>
<thead>
<tr>
<th>Week</th>
<th>Lesson Plan</th>
<th>Research Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Overview of other statistical techniques, including linear regression models; course review, course evaluations; completion of final exam</td>
<td>Provided written feedback on CM 6 concept maps; shared CM7 concept maps and discussed experiences with concept mapping; field notes; researcher journal; key informants completed journal entries; participants completed Questionnaire; final interview conducted after final course grades officially recorded</td>
</tr>
</tbody>
</table>

notes from that day. As I reviewed and graded concept map assignments and problems sets during the two-week break, I added additional reflections to my journal. I also incorporated notes based on any student communication I may have had during the two-week break between class sessions.

I conducted initial interviews with seven of the eight key informants. One key informant, Anna, had health issues during the term and opted not to participate in the interviews. Interviews between the key informants and myself were conducted in a spare faculty office on campus and audio-taped using a conventional cassette tape recorder and lasted between 5-10 minutes. Three of the interviews took place at the end of the second class session. Three others took place during the week after the second class session. The remaining initial interview was conducted the morning of the third class session prior to the beginning of class. This interview had been rescheduled from an earlier date due to illness of the key informant’s family members. These interviews were then transcribed into Microsoft® Word documents to allow for coding and analysis. I conducted one final
key informant interview with Matthew that lasted approximately 30 minutes. This interview took place after the final grades were officially recorded by the College Registrar, and it was also audio-taped and transcribed as a Microsoft® Word document. The other key informants did not participate in final interviews for various reasons. Three of them opted to identify themselves on the questionnaire in lieu of the final interview. Additionally, some of the participants who did not participate in the final formal interview indicated to me that they felt they had expressed their opinions fully through not only the questionnaire but also in the final class discussion regarding concept maps, in their journals, and in informal conversations with me, which I documented in my field notes. I did contact the key informants a maximum of five times, in-person, via email and phone to request a formal interview; 1 out of 8 were able to participate.

Three key informants, Geoffrey, Carol, and Cynthia, completed the key informant journals. They completed their entries according to the schedule given in the journal prompts provided to them upon their consent to become key informants. I offered key informants the options of submitting their journals in a sealed envelope that I would open after their final grades were recorded or of electronically submitting their journals via email or the secure course management system after grades had been recorded. Geoffrey and Carol opted to email their journals in the form of Microsoft® Word document attachments two days and one day before the last class session, respectively. I did not open the attachments until grades had been officially recorded. Cynthia provided me with a hand-written document that was not in a sealed envelope at the last class session. I placed her journal in an envelope in a locked filing cabinet and later transcribed her
journal into a Microsoft® Word document after grades had been officially recorded. I maintained the key informant journals on a password-protected computer.

During the study I collected various documents created by the participants. These documents included concept map assignments, problem sets, and exams. The concept maps and problem sets occasionally included a personal note from the student to me. The contents of the notes varied. Examples include content-related questions, elaboration of strategies or approaches undertaken by the student on the assignment, and expressions of frustration regarding concept mapping or a particular problem. I included summaries of these notes and my responses in my journal.

Concept map assignments were due at each class session. Before I collected the maps, students were invited to share their maps with the class. Some students discussed them from their seat while others occasionally presented their maps on the chalkboard. Discussions focused on the content and arrangement of the maps as well as on the general process and experience of constructing the maps. After I collected the concept map assignments at the end of each class session, I made photocopies of the submissions in the adult studies office. During the break between class sessions, I provided written feedback on the original submission. I then scanned both the photo-copied versions and the original submissions with feedback into PDF documents. I then printed them out, removed any identifying information and personal notes and scanned them into PDFs once again which I stored on a personal computer that was password-protected. I then deleted the original scanned copies. I returned the original concept map assignments with
my written feedback to the students at the next class session, and often I would discuss the feedback with individual students during class breaks or after the class session.

Problem set assignments were collected at six of the seven class sessions. I reviewed and graded the problem sets and exams and returned them at the following class session with written feedback. When reviewing these assignments, I compared them with the corresponding concept map assignments. I looked to see if the concepts and propositions presented in the concept maps aligned with how they discussed, used, or integrated those concepts in the problem sets or exams. I added these findings to the observations in my journal.

I distributed the questionnaire on the final class session at the beginning of class. I explained that I would leave the classroom for a period of time while they completed the questionnaire. I asked for a volunteer who collected the questionnaires and sealed them in envelopes. This volunteer then retrieved me when all questionnaires had been completed and collected. I reminded the students that the questionnaire was to be completed anonymously and that their completed questionnaires would remain sealed until after grades had been officially posted by the Registrar’s office to the students’ permanent records. I encouraged them to be as candid and illustrative as they felt comfortable. When I returned to the classroom, three of the key informants revealed that they had chosen to identify themselves on the questionnaire.

**Role of the Researcher**

The role of the researcher in this study was multi-fold. I was instructor, observer, and analyst. The goal of this case study was to produce a rich multi-layered description
of students’ experiences with an initial implementation of concept mapping as a learning strategy in my introductory statistics course. To achieve a rich and well-balanced description, the analysis detailed the experience from the instructor’s as well as from the students’ perspectives. Data collected included a reflective journal that captured the instructor’s experience of creating and incorporating the concept mapping materials as well as experiences and observations of the instructor during classes. In the instructor role, I endeavored to foster no intimidation, including any perceived effects on course grades or instructor support, regarding the student’s choice to engage in research activities, such as allowing documents to be analyzed or consenting to be a key informant. In addition, I strove to create a safe environment for sharing perceptions and feelings regarding the implementation of concept mapping. To the roles of observer and analyst, I brought to the field the experience, training, and perspective of a statistics instructor, a professional statistician, and a former graduate student in statistics. This background provided the advantage of understanding the language of statistics and the context and content of the typical elementary statistics course. However, I was concerned about introducing a bias into the interpretation of the participants’ responses caused by having the perspective of a statistics instructor. As a statistics educator, I may have possessed different perspectives and insights on the motivations and approaches incorporated in the course design than a student may have. In addition, my extensive statistical experience may have presented itself as a barrier to empathetic understanding of the experiences of a beginning statistician. In order to enhance the credibility and confirmability of the research, I carefully reflected on and managed any sources of
potential biases that arose during the process or because of my background. Peer examination was utilized to enhance the credibility of the researcher. The peer examiner was a colleague in mathematics and statistics who reviewed the initial construction, developed by the researcher from the data, of the description of the participants’ collective experience with the use of concept mapping in statistics instruction. The description was reflected upon and modified as necessary based on any recognition by the peer examiner of researcher bias.

**Data Analysis**

Creswell (1998) described the researcher performing data analysis as “working inductively from particulars to more general perspectives” (p. 20). Although there is not a consensus on one single way to analyze qualitative data, Creswell stressed the importance of ultimately creating a narrative that provides a multi-layered description that accurately represents the experiences and voices of the participants. Of key importance is “Do we have it right?” (Stake, 1995, p. 107). This section details the procedures and strategies employed to analyze the data collected in my case study.

**Procedures**

Stake (1995) and Creswell (1998) recommended five important strategies specific to case study research. In addition, the research focus and context of this particular study necessitated incorporating elements of phenomenological and heuristic analysis.

Data analysis was performed using four strategies espoused by Stake (1995): categorical aggregation, direct interpretation, patterns, and naturalistic generalizations. Categorical aggregation refers to the accumulation of instances into a collective meaning
regarding a particular issue. In direct interpretation, the examination is on a single instance. However, this single instance is not necessarily literally recorded. Rather, the task of the researcher is to synthesize the instance, that is, to “pull it apart and put it back together again more meaningfully” (Stake, 1995, p. 75). Stake further contended that both categorical aggregation and direct interpretation rely on the search for patterns, or correspondence among categories or meanings. The fourth strategy,

Naturalistic generalization is a process where readers gain insight by reflecting on the details and descriptions presented in case studies. As readers recognize similarities in case study details and find descriptions that resonate with their own experiences; they consider whether their situations are similar enough to warrant generalizations. Naturalistic generalization invites readers to apply ideas from the natural and in-depth depictions presented in case studies to personal contexts. (Melrose, 2010, p. 599)

Naturalistic generalization, then, relies on the intricate and detailed description of the case. Indeed, Creswell recommended a fifth strategy be added to Stake’s list of data analysis and interpretation strategies, that is, description, “a detailed view of aspects about the case” (Creswell, 1998, p. 154).

Finally, the data analysis incorporated aspects of phenomenological and heuristic analysis. Elements of phenomenological analysis such as horizontalization of the data into meaning units helped to make the description of the case. In addition, in light of the researcher-as-participant role included in the study, personal meaning as experienced by
Validity and Reliability

Questions of validity and reliability can be controversial in qualitative research. According to Merriam, “internal validity deals with the question of how research findings match reality” (1998, p. 201). However, “one of the assumptions underlying qualitative research is that reality is holistic, multidimensional, and ever-changing” (p. 202) and “reality is constructed by individuals interacting with their social worlds” (p. 6).

Therefore, it was the goal of the researcher to as accurately as possible reflect the realities constructed and related by each individual subject in order to present an unbiased, holistic interpretation.

Merriam (1998) offered several strategies to engender internal validity. In order to ensure triangulation, the use of multiple and varying data sources in order to increase the credibility of the results, I made use of reflective journals, my own and the key informants; key informants’ interview transcripts; study participants’ concept maps and other documents; study participants’ questionnaires; field notes, and informal observations. Member checks were used upon transcription and analysis of the journals, interviews, and field notes in order to ensure the accuracy of the recording and interpreting of the participants’ perspectives. The semester-long immersion into the case setting increased the validity of the findings by generating substantive data and by minimizing misinformation (Creswell, 1998). Peer examination was incorporated as
described in the Role of the Researcher section. Researcher bias was controlled as part of the strategies outlined above and also in the Role of the Researcher section.

Merriam recommended “clarifying the researcher’s assumptions, worldview, and theoretical orientation at the onset of the study” (1998, p. 205). In addition to Merriam’s recommendation, Groth (2010), in discussing the validity of qualitative methodologies in statistics education research, contended that first a position must be taken regarding one’s philosophical orientation towards research. In deciding that position for this research, I also considered my philosophical orientation toward learning and knowledge. My perspective, aligned with the radical constructivist view championed by von Glasersfeld (1995), is one that rejects positivism in favor of a belief that knowledge is not a fixed reality or truth. Rather, knowledge is constructed by the individual and dependent upon previous experience and context. This position is also in concordance with the definition of statistics used in this study that statistics is an art as well as a science that involves interpretation based on context.

Additionally, the issues of reliability, generally characterized by the repeatability of the study, and external validity, the generalizability of the study, were considered. Repeatability is difficult when exploring perceptions and individual experience due to the dynamic nature of human thought and behavior. However, great strides were taken to ensure as much as possible that under instances of consistent realities, across person or points in time, the interpretations made by the researcher were the same. Regarding generalizability of the study, the lack of traditional sampling procedures may prevent the study from being generalized to larger samples or similar cases, and therefore, may be
considered a limitation of the study. However, the heuristic analysis approach of the study brings a unique story to the results that is compensatory for any lack of generalizability and may provide a model for metacognitive activity in similar settings. In addition, Creswell (1998) addressed transferability, as likened to generalizability, and contended that the thick description that results from the case study approach provides ample detail of the setting so that readers may ascertain the transferability of the findings to other situations based on a comparison of the settings.

**Pilot Study/Prior Work**

This study was motivated by an earlier project undertaken by the researcher to gain an understanding of the essence of the experience of statistics instruction as perceived by postsecondary students. A phenomenological approach was taken in order to “understand the meaning of experiences of individuals” regarding the phenomenon of experiencing statistics instruction.

**Procedures**

Consistent with a phenomenological study, the data collection consisted of in-depth interviews. Since this study was serving as a pilot study, extensive interviews were conducted with only two participants. The two participants were both Caucasian American females in their 40s. Over a series of one-on-one interviews with the researcher, the participants shared detailed recollections about their classroom experiences in introductory statistics courses. In particular, they described classroom procedures and routines, instructional strategies, and classroom culture and atmosphere. In addition, the participants responded to specific questions about valuable or detrimental
approaches and actions of the instructor as well as questions concerning the impact of the
statistics instructional experience on their perception of their knowledge of, comfort with,
and sense of utility regarding introductory statistics concepts.

Findings

Interview transcripts were carefully analyzed and distinct statements
characterizing the experiences of the participants were identified. These statements were
categorized into five distinct meaning units that described the phenomenon of statistics
instruction as experienced by the participants. Three of the five meaning units focused
on the instructor. These units were labeled as impact of instructor, characteristics of
instructor, and instructional approaches. The other two meaning units were identified as
anxiety and gender. However, key statements classified under these meaning units were
inextricably linked to the instructor as well.

The meaning unit identified as impact of instructor included several descriptions
of ways in which the participants’ perceptions were impacted. Key themes involved the
impact of the experience on students’ perception of knowledge of statistical concepts and
their ability to make connections of statistical concepts to real situations. In addition, the
participants indicated a relationship between success in the course and their perception of
understanding gained from the instruction with their comfort level and attitude regarding
using statistics.

The meaning unit labeled as characteristics of the instructor included personality
characteristics, classroom organization and instructional approaches, and perceptions of
competency. A key finding from this thread, however, appeared to be that the students’
perceptions of the instructor profoundly impacted their perceptions of the subject of statistics.

Instructional approaches perceived negatively included excessive lecturing, an emphasis on formulas, and encouragement of memorization without context or application. Instructional approaches perceived positively included the use of outlines and handouts, computer use, collaborative activities, and realistic problem solving.

The category regarding anxiety highlighted feelings of apprehension based on preconceived notions regarding statistics and mathematics, the instructor, and the participant’s previous experiences. Also, specific actions, attitudes, and behaviors of the instructor during the course created anxiety for the participants, which impacted their perceptions regarding their experiences, including their perspectives on their ability to understand and use statistical concepts.

The gender meaning unit highlighted two key issues both of which were linked to the instructor. The first was a feeling of females being made to feel or being viewed as inferior to males by the instructor. Second, the participants shared feelings of being uncomfortable with their experience because of perceptions of low regard or harassment from the male instructor.

Conclusions and Implications for Current Study

Based on these findings, I decided to implement concept mapping into the course and to examine the experience of this implementation in an attempt to understand the possible impacts of this strategy. Specific statements made by the participants echoed common findings in the literature regarding procedural versus conceptual understanding.
(Broers, 2002; McGatha et al., 2002; Mokros & Russell, 1995; Shaughnessy & Pfannkuch, 2002; Shaughnessy et al., 1999; Watson & Moritz, 1999, 2000a, 2000b). For example, one participant stated, “if I’m given a formula and I could plug things into it, but . . . if I actually have to figure out which statistic I’m supposed to use when and why, and actually do it, I don’t know that I would feel qualified.” The rationale behind using concept maps is that they may develop a connected and integrated understanding of the concepts that may promote deep understandings and the ability to connect concepts in real settings (Baroody & Bartels, 2000; Chiou, 2008; Hasemann & Mansfield, 1995; Horton et al., 1993; Novak, 1990, 1995).

Furthermore, the meaning unit involving instructional approaches reveals that students are eager to move away from traditional lecturing approaches and presentation of formulas without connections among concepts or application to realistic contexts. In addition, positive feelings about less traditional approaches to learning such as the use of technology, collaboration, and the incorporation of realistic settings, indicate that students may be open to an alternative instructional strategy such as concept mapping. Also, their appreciation and reliance on outlines suggest that a hierarchical organization tool such as a concept map may be viewed as beneficial.

The results showed that students’ perceptions about the material, including their knowledge, comfort, and sense of utility, were confounded with their feelings about the classroom environment and in particular their feelings regarding the instructor. Because of the confounding of the influence of the instructor with nearly all aspects of the experience with instruction in introductory statistics, further research should involve
more sources of data. The case study methodology will allow for the triangulation of data, which will allow for a more complete depiction of the experience and the ability to separate confounding factors potentially influencing a participant’s perspective.

While the composition of the sample was not diverse in terms of gender and race, it was not markedly unrepresentative of the population of the university, which served as the potential pool of participants. However, considering that gender emerged as an issue relating to the participants’ perspectives regarding their experience with statistics instruction, it is prudent to attend to issues of demographic diversity as much as possible in the given case setting.

**Summary**

This chapter reviewed traditions in statistics education research and my rationale for selecting a qualitative research design based on its alignment with my research focus. Specifically, based upon further consideration of my research questions, I provided justification of my use of an instrumental case study to examine how students experience the learning of statistics with the specific instructional strategy of concept mapping. In addition, I detailed the study design, including setting, participants, data collection, and data analysis. I also addressed issues of researcher bias, triangulation, and other issues of validity. Finally, I documented a pilot study that I conducted the results of which directed both the focus and design of the study for this current research.
CHAPTER IV
CASE ANALYSIS

The purpose of this instrumental case study was to examine the potential of concept mapping as a learning tool in an introductory statistics course. I wanted to document the experiences of myself as the instructor and my students’ experiences with the initial implementation of concept mapping as a learning tool into my course. This case study sought to inform the following research questions:

1. How do students experience the learning of introductory statistical concepts through the use of concept mapping?

2. How do students in an introductory statistics course perceive the impact of their use of concept mapping on their ability to relate and apply important statistical concepts?

Through interactions with the participants and upon analyzing the data, it became clear that the participants were clearly distinguishing between their ability to relate statistical concepts to each other and to apply statistical concepts to statistics exercises and other data analysis situations. Therefore, I began to divide Research Question 2 into two sub-questions:

2a. How do students in an introductory statistics course perceive the impact of their use of concept mapping on their ability to relate important statistical concepts?
2b. How do students in an introductory statistics course perceive the impact of their use of concept mapping on their ability to apply important statistical concepts?

The research questions were explored through the analysis of the experience of all research participants and the general case setting. Then the research questions were further examined through the lens of each of the key informants.

**Research Participants**

This section provides a description of the case formed by analyzing evidence from all research participants, both study participants and key informants. I begin by informing this description by explaining the selection process of the research participants. Then I describe how concept maps were incorporated into the course both inside and outside of the classroom. Finally, I analyze the results of the questionnaire as they inform my research questions.

**The Case: “Stats Intro”**

A representative class in the Weekend College is comprised of adult students and traditional students who have many other obligations. The typical adult student is juggling full-time work, family, community, and school obligations. Although the traditional students may not have extensive family obligations or full-time work commitments, I have found that often traditional students choose to enroll in a Weekend College course because they have commitments that may be uncharacteristic of a typical traditional student. That is, some are working a part-time job that requires almost as many hours as a full-time position, some are engaged in leadership roles in campus
organizations, and others are immersed in scholarly research projects. Weekend College courses are designed to require less classroom time—28 contact hours per term versus 48 contact hours in a traditional course—while assuming a greater degree of independent learning. I anticipated the potential of many of the aforementioned obligations and conflicts to impact the level of participation in this study. However I felt that these conflicts and obstacles were a common occurrence in my classes, and, therefore, incorporating these into the study would more authentically represent the expected experience of incorporating concept mapping into this course in the future. As mentioned in the previous chapter, the introductory statistics course at this institution generally has been in high demand due to the course being a requirement for several majors as well as serving as an elective course meeting a “core curriculum” designation. For purposes of this study, I refer to this course as “Stats Intro.” I have already provided a breakdown of the members of the class (see Table 1 in Chapter 3).

**Field Notes**

Here is what I wrote in my reflective journal before the first class:

I am excited to be starting a new semester in the weekend college. I am happy that we started a week later in January than we sometimes do. I think the students will be more refreshed after a longer holiday break. However, we now have back-to-back weekends for the first two class sessions. That often puts more pressure on the students as they lose that “off” weekend to complete their assignments. They will need to juggle their school work with their work and
family obligations this week. I am just glad it is early in the semester instead of near mid-terms.

I am curious to learn of the composition of the class and observe their personalities. I know the large majority of students are graduating seniors. This often increases the overall anxiety level of the class. Not only are they feeling the pressure of performing in this class that they are not looking forward to, but they now feel that their entire academic career and timely graduation depend on it. I know this isn’t the case for all of the seniors. The traditional students typically have not been able to enroll in the introductory statistics class earlier because of the enrollment limitations. However, the Weekend College (WEC) students have first priority in the WEC classes so they would not have been closed out if they had chosen to take it earlier in their academic careers. I need to remind advisors again to encourage those students who are afraid to take this course to take it earlier when the stakes are not as high.

I am not quite sure what to expect about how the students will feel about the concept mapping. Typically the WEC students are very dedicated. They are used to completing the initial assignment before the class starts. So I know that most of them will have read the concept map material and will come in with questions. However, given the anxiety and pressure many of them are likely feeling, I am not sure how much they will embrace a new learning strategy. Typically the students have well-formed habits, and given the typical age range, they are used to a fairly conventional lecture-type classroom. It seems like the
active learning and constructivist approaches that I try are often met with mixed success. There have been many times when I have tried different instructional strategies in class, such as problem-solving in pairs and small groups or having them experiment with simulations and other technologies. They seem to go along with it for a few minutes and then they ask “when are we going to get back together as a large group so you can teach us and demonstrate this topic?” Also, I recall the comments of students from past semesters who remark that they do not rely too much on the advance organizers that I provide them. They say things like, “I can’t make any sense of it until you explain it and show it to me in class, so I don’t really read them before class.” So even though I believe they will be respectful and try to fulfill the requirements of the course, I still am not sure how they will embrace a new approach.

The other concern that I have is with the number of traditional (TRAD) students in my class this time. I usually have a couple traditional students, but this time I believe it is evenly split between WEC and TRAD students. I think the TRAD students are more accustomed to active learning opportunities in the classroom. However I think some of the TRAD students taking the weekend college class don’t take it as seriously. They feel like the pace of the course gives them more flexibility in their studying and doesn’t require as much dedication as a class that meets two or three times per week. Oftentimes because TRAD students are allowed in the WEC courses only by permission, the students tend to be stronger students. Therefore I am thinking they might not feel the need to
embrace a new learning tool because they’re already confident in their abilities to learn the material in their traditional ways.

Each class session held roughly to the same structure. I have summarized a typical class schedule in Table 4. I began by inviting general questions. Those questions typically involved administrative details, such as due dates, future assignments, and exams schedules; assistance with homework problems; clarifications on concepts; and discussion of past assignments. There were also regular requests to work through problems that demonstrated specific concepts that we had discussed previously. Sometimes there were questions about the concept maps. After this general question session, we would then conduct a detailed discussion of our concept maps from the previous week. I have used the word week in this context to represent each session of the course; for example, there were seven work weeks over the course of the 12-calendar week term. The students were asked to talk about their concept maps and to illustrate them on the board if they desired. On several occasions I would share my own concept maps. Sometimes I drew them on the board with input from the class. At other times I wrote my concept map on the board before the students arrived, and then we would discuss it as a group. The students were also encouraged to discuss how they were feeling about the process of concept mapping and how it was affecting their learning of statistical concepts. Many students took this opportunity to share their difficulties with the process and to offer tips or advice on how to construct the maps. After each week’s concept map discussion, the students were encouraged to revisit and revise their concept maps and to build upon them throughout the term. After this discussion, we would
typically take the first of two breaks during the class. A four-hour class block is challenging, especially given that the class convenes at 8:00 AM on a Saturday morning. Many of these individuals have worked a full work week and have attended a four-hour class on the previous night. Therefore, breaks are needed to allow the students, and the instructor, opportunities to get re-energized. Also, students often take these breaks as an opportunity to speak with me one-on-one about a concern or question they have regarding the class.

Table 4

*Summary of Activities of Typical Class Session*

<table>
<thead>
<tr>
<th>Class activity</th>
<th>Approximate duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>General questions about the class: administrative details, assignment questions, clarification of concepts</td>
<td>10–30 minutes</td>
</tr>
<tr>
<td>Concept map discussions: questions about the process, sharing previous maps</td>
<td>20–30 minutes</td>
</tr>
<tr>
<td>Break: students “stretch their legs,” informal conversations</td>
<td>10–15 minutes</td>
</tr>
<tr>
<td>New topics work session: lectures and discussion, problem-solving, computer use</td>
<td>60–75 minutes</td>
</tr>
<tr>
<td>Break</td>
<td>10–15 minutes</td>
</tr>
<tr>
<td>New topics work session (continued)</td>
<td>60–75 minutes</td>
</tr>
<tr>
<td>Conclusion: summary of class session; overview of upcoming class session and assignments</td>
<td>5–10 minutes</td>
</tr>
</tbody>
</table>

The next part of the class session consisted of our discussion of the new material. This part of the class session was done in the typical way I have taught the course in the
past. Students received a set of what I refer to as course notes prior to every class. These documents were posted on our learning management system. The students knew to download them and review them before class along with reading the appropriate text section before the class meeting. These notes served as advance organizers and as the basis of our classroom discussions. They included definitions and explanation of concepts as well as practice problems. On the document I allowed space for the students to add any additional comments on the definitions or concepts as the result of our class discussions. I also left room for them to show their work and to write how we solved the practice problems in class. We discussed the concepts as a group and we worked on problems as a whole group, in small groups, or in pairs. We also used technology to demonstrate concepts, run simulations, and assist with calculations.

We did not develop concept maps in class when we were discussing new material because the emphasis of my study was exploring the experience of student-created concept mapping. To this end, I wanted the concept maps for newly presented topics to be constructed by the students to reflect their individual understanding of the concepts and to not be influenced by instructor-created or collaborative maps.

To inform Research Question 1, I wanted to explore how the research participants experienced the use of concept mapping in the course. Concept mapping was introduced as a supplemental learning tool in the course. Prior to the beginning of the course, the enrolled students were given a letter explaining that concept mapping would be used in the course (see Appendix E). They were also given a written tutorial on concept mapping (see Appendix F). This tutorial introduced the key terms and the process used in
constructing concept maps that were described in the Concept Maps section of Chapter 1. This document also contained a brief explanation of the origin and theory behind concept mapping, concept map examples, links to online resources for further information on concept mapping, and links to concept mapping software for creating maps electronically.

On the first day of class, we spent about 45 minutes reviewing the concept mapping tutorial. The students had already read through the concept mapping tutorial and completed their first two concept maps as part of their initial assignment for the start of the term. We briefly discussed the origins and philosophy of concept mapping. Then we reviewed the key terms and steps of the concept mapping process that I had provided in the written tutorial. A summary of these terms is provided in Table 5. We first discussed how to come up with a main topic for the map or a focus question. Then we talked about brainstorming the key ideas or concepts related to this topic. I recommended that they list these topics in the parking lot, and we discussed options for representing the parking lot. The concepts could be represented as a list of words on paper. Alternatively, individual index cards or sticky notes could be used for each concept so that they could be moved around easily. This may have the potential to make the process of developing the hierarchy and representing the propositions less cumbersome. We discussed the next step of linking concepts together with an arrow or line and adding linking words to form the propositions. There were some questions about what exactly a proposition is and how to correctly form one. I explained that a proposition is simply a statement of how two ideas are related or connected to each other.
Our review then continued with a discussion of cross-links. As the map progresses downward through the hierarchy, the map tends to branch out in different directions from the higher concepts, forming map segments. The concepts in these different map segments are often related in some way as well. These relationships are represented by cross-links. We also discussed including specific examples at the lowest level of the map to clarify concepts. Many participants noted that these examples were helpful for making the ideas and the relationships in the maps more tangible.

Table 5

*Key Terms Used in Concept Mapping*

<table>
<thead>
<tr>
<th>Term</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concept</td>
<td>A label assigned to a regularity in an object or event</td>
</tr>
<tr>
<td>Parking Lot</td>
<td>A ranked list of concepts for the map</td>
</tr>
<tr>
<td>Linking word or phrase</td>
<td>A word or phrase that combines concepts into a meaningful statement</td>
</tr>
<tr>
<td>Arrow or line</td>
<td>The physical connector of two concept nodes</td>
</tr>
<tr>
<td>Proposition</td>
<td>A unit of meaning consisting of concepts and linking words</td>
</tr>
<tr>
<td>Hierarchical Structure</td>
<td>The top-down organization of the map from broad, inclusive concepts to specific concepts</td>
</tr>
<tr>
<td>Map segment</td>
<td>A sub-domain of the main domain of the map</td>
</tr>
<tr>
<td>Cross-link</td>
<td>Links that connect distinct map segments</td>
</tr>
<tr>
<td>Example</td>
<td>A specific illustration of a particular concept</td>
</tr>
</tbody>
</table>
In this, and subsequent, class discussions regarding concept mapping, I endeavored to limit my comments to discussing the mechanics of concept mapping, answering specific questions about concept mapping, and responding to participant’s sharing of their concept maps. I tried to refrain from discussing what I perceived or what research has reported to be the benefits of concept mapping so that the students could decide for themselves if concept maps were helpful. In general, I tried not to make specific value statements about attributes of concept mapping that I would be asking them about in the questionnaire at the end of the term. However, the concept mapping tutorial contained a section briefly outlining in bullet form some potential benefits of concept mapping that have been found through previous research. Perhaps I should not have included this in the tutorial, but as their instructor, I wanted to provide them with some rationale for engaging in this activity. It is conceivable that this inclusion may have suggested possible answers for some of the questions on the questionnaire, including the question asking them to state their perceived benefits of concept mapping. In addition, in informal discussions with individuals who were struggling with concept mapping, I made statements such as “some students have found concept mapping helpful to organize their understanding or to make connections between concepts, but it may or may not work for you.” These conversations also may have served to suggest possible responses to the questionnaire prompts.

The next part of our discussion focused on the concept maps that they had created for the first assignment. The tutorial contained the first concept mapping assignment asking the students to create two concept maps. The first concept map they were to
construct, which I refer to as CM 1.1, was for the topic, “The Game of Basketball.” The students were given a list of pre-selected concepts related to basketball and were asked to complete the map by organizing the concepts and creating links that would represent their knowledge of the game of basketball. The instructions to the students for completing CM 1.1 are shown in Figure 2. Most students felt comfortable constructing this map because they were fairly familiar with the topic and because I had provided them the concepts. They did express some initial challenges. They felt like it was time-consuming to position the nodes correctly. Most people were fairly comfortable linking the concepts together. That is, they knew how they wanted to represent their knowledge of the game or the relationships between the concepts I had given them, but it required a few iterations to get the physical placement of the nodes on paper so that they could create visually appealing links and structure. We talked about ways to make this easier by revisiting our discussion of using sticky notes or index cards for the concepts and moving these items around on a flat surface until they had the structure they desired. Then they could copy those concepts onto paper or to their software and create the links.

The second concept mapping exercise, CM 1.2, asked students to create a map representing a personal area of interest. The students were required to select the key concepts for the map as well as to organize and link the concepts in order to represent their knowledge of their chosen topic. The range of topics selected was diverse. Examples included other sports, hobbies, concepts from other disciplines, job responsibilities, and personal responsibilities. Figure 3 shows Kathy’s concept map for the topic of music. Based on a review of these maps and on the class discussion, I
To practice your emerging knowledge of concept mapping, I have provided below a list of concepts, what Novak calls the “parking lot”, regarding the game of basketball. Use your understanding of basketball, the concepts provided, and your own linking words and phrases to develop a concept map of The Game of Basketball. You may also add examples if you like. You may create your map with pencil and paper; word-processing, presentation, or other software; or automated concept map tools (see the list of resources in the concept mapping tutorial).

![The Game of Basketball]

**Figure 2.** Instructions for students for their first concept map assignment.
surmised that the students were fairly comfortable with the basic process of concept mapping. Their challenges appeared to be mainly related to showing the appropriate hierarchy, moving from inclusive to more specific concepts, as well as choosing linking words that would create meaningful and grammatically correct statements. Some of the participants expressed that they felt comfortable with concept mapping because they had mapped subjects with which they were familiar and confident. However, they also expressed concerned that when they started to construct concept maps for statistical concepts, they would have greater difficulty in expressing their understanding. Many participants also expressed concerned over the time involved in constructing the maps,
but at this point they were hopeful that the strategies we had discussed and their growing familiarity with the process would lessen this burden over the term. Kathy explained,

I think the concept maps take a lot of time to do. The first couple ones they take quite some time, but I think once I get the hang of it it’s going to start going smoother, and it will be easier and won’t be so time consuming. All in all I think they’ve been helpful so far.

We concluded our concept map training with a brief discussion of using software to construct concept maps. Some students indicated that they used word processing or presentation software to construct their concept maps. They indicated that this made it easier for them to cut and paste their concepts and arrows when they wanted to reposition parts of their map. Several of the students had started to work with the CmapTools software that I recommended in the concept mapping tutorial. CmapTools is a software program developed by the Florida Institute for Human and Machine Cognition (IHMC), for which Joseph Novak is a Senior Research Scientist. CmapTools allows users to construct concept maps, share and link maps with other users on the Internet, and search for others’ maps. The software contains a map editor with a user-friendly interface that allows for easy construction and editing of maps through a drag-and-drop operation. The students who were using CmapTools actually encouraged the other students to try it. They tried to assure them that the software was fairly easy to learn and that they could quickly be able to use the primary features of the tool to produce a basic concept map even if the students felt they were not technologically savvy. While I encouraged the use of this or any other software of the student’s choosing, I did not require it. I am
conscious of the comfort level with technology of many of the adult students in my classes. While I introduce and incorporate various technologies that would help with statistical concepts and calculations, I encourage their use to the extent that the students are comfortable. The primary goals of the class are focused on statistical literacy, and I am mindful of adding what some may view as the additional burden of learning technology.

We began our discussion of statistics on the first day of class by discussing broad purposes and methods in statistics. I explained that the course would proceed by first exploring ideas in descriptive statistics and then building upon these ideas to examine topics in inferential statistics, and we discussed distinctions between the two areas. Table 6 provides an overview of the weekly lessons throughout the term. To launch our discussion of descriptive statistics, the students completed a brief anonymous survey with general and lighthearted demographic questions, such as “do you like sushi?” and “how many pets do you have?” We used this survey not only as an icebreaker, but also as the basis for our discussion of basic statistical terms. Later in the term, the students prepared a brief data analysis based on the survey results for a homework assignment. This assignment gave them the opportunity to practice the application of the descriptive statistical measures we had discussed in the first two weeks of the term. The remaining weeks of the term followed closely to the typical schedule outlined earlier in Table 4.
### Table 6

*Overview of Weekly Lessons*

<table>
<thead>
<tr>
<th>Week</th>
<th>Description of Topics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A broad hierarchy of statistics and terminology were presented. The importance of appropriate sampling as well as various data gathering and sampling methods were explored. Also discussed were graphical descriptive measures, visual/pictorial representations of data, used to summarize and present data and to illuminate key characteristics of data.</td>
</tr>
<tr>
<td>2</td>
<td>This unit focused on univariate numerical descriptive measures, single or sets of numerical calculations or values that summarize and characterize data.</td>
</tr>
<tr>
<td>3</td>
<td>An overview of bivariate descriptive statistics was given. In addition, properties and applications of random variables and probability distributions for discrete data were discussed.</td>
</tr>
<tr>
<td>4</td>
<td>Properties and applications of random variables and probability distributions for continuous data were discussed. Particular emphasis was placed on the normal distribution, including the standard normal distribution and applications of the normal distribution. The mid-term exam was administered this week.</td>
</tr>
<tr>
<td>5</td>
<td>The theory and applications of sampling distributions and the Central Limit Theorem for the mean were examined. The concept of estimating population parameters by sample statistics was examined, with particular emphasis on the theory and applications of interval estimates.</td>
</tr>
<tr>
<td>6</td>
<td>Parametric inferential techniques for making predictions and testing conjectures for a population based on sample information were discussed.</td>
</tr>
<tr>
<td>7</td>
<td>An overview of other statistical techniques, including linear regression models, was presented. The final exam, course evaluation, and concept map questionnaire were administered this week as well.</td>
</tr>
</tbody>
</table>

Each student had a weekly assignment of constructing a concept map to represent his or her understanding of the concepts discussed in the previous class session. A summary of all concept map assignments for the term and their associated topics was presented in Table 2 in Chapter 3. These concept maps were graded, and the concept mapping average constituted 15% of their final course grade. I did evaluate the main components of concept maps that are generally examined when assessing concept maps,
which are the inclusion of key concepts, the arrangement or hierarchy of the map, the links, and the layout and readability of the map. However, I mainly rewarded the perceived effort that went into constructing the maps, and I explained that their maps would be scored primarily based on completion. I decided to grade the maps to provide an incentive for their completion. In addition, I am committed in all my classes to offering varied forms of assessment so that students have multiple opportunities to demonstrate their understanding and to uncover their misconceptions or needs for improvement. The remaining 85% of the course grade was based on weekly problem sets, two exams, and attendance and participation. The problem sets included straightforward exercises requiring the application of one or two explicitly stated concepts, problems that required the identification of the appropriate concepts and techniques to be used, and small-scale data analysis and inference projects that called on higher levels of statistical reasoning.

Students were encouraged to create and use their concept maps in any way and to the degree they felt comfortable. Some students chose to create the concept maps before they attempted the problem sets assigned for that weekend while others completed their problem sets first and then created the concept maps. A few of the participants indicated they did not have a set order for completing these two assignments each week. Some of the students who constructed the concept maps first felt that it was a good way to review and organize the concepts that they would need to complete the problems. Some of these respondents indicated that they then used their concept maps as a guide to help them apply the concepts to solving the problems. Several of the participants who constructed
the concept map after completing the problem sets expressed that using their notes and
the textbook helped them solve the problems. Then they constructed the required concept
maps based on the concepts and processes that they had used when solving the problems.
The students who indicated they had no particular order to completing the problem sets
and concept maps each week indicated that they felt both types of assignments were just
assessments that were required for the course. They did not feel like one informed the
other. These three different approaches to completing the weekly assignments informed
Research Question 1 in that three classifications emerged of how the students learned
statistics with concept mapping. The first category of students viewed concept mapping
as a way to organize and integrate their knowledge in order to apply it to solving
problems. The second group viewed concept mapping as a way to represent their
knowledge for the purpose of external assessment. The third classification of students
experienced concept mapping as an added requirement of the course. These students did
not feel that the concept maps impacted their learning or their ability to use statistical
concepts and techniques.

**Questionnaire**

The research participants completed the questionnaire regarding their use of
concept mapping in the course at the end of the term. To maintain their privacy as well
as to honor my commitment that their participation and their opinions about the use of
concept mapping in the course would not impact their grades in the course, I asked them
to complete the questionnaire anonymously and place them into envelopes that would be
sealed by a volunteer in the course. I did not open these envelopes until after the final
grades had been submitted and posted into the official record by the registrar of the college. However, as previously mentioned, several of the key informants indicated that they chose to identify themselves on the questionnaire and use that in lieu of their final interview.

Analysis of Questionnaire

The questionnaire consisted of 8 open-ended questions. All 12 research participants completed the questionnaires. Two respondents did not provide an answer for the last question. In total, there were 94 comments. The questions were analyzed individually and the responses were coded by like ideas, phrases, and keywords. Some participants’ responses were given multiple codes if they contained more than one idea or keyword. Therefore, the total number of the key statements or meaning units for some of the questions exceeds the number of research participants. In the sections below, I have provided a summary of the responses to each question as well as frequency tables by code representation.

Question one. The first question asked about previous concept mapping experience. Table 7 shows the frequency distribution of answers for this question. Six of the 12 respondents indicated that they had no previous experience with concept mapping. Three respondents indicated previous experience with concept mapping in school settings, two respondents stated that they had used mind mapping, and one respondent described using something similar to concept mapping. This respondent stated,

I had seen it [concept mapping] before in some classes but not as something that I created, and in writing classes there is a similar method to help brainstorming for
ideas but it is fundamentally different in nature, meant more so to connect ideas for papers rather than show knowledge or “concepts.”

Table 7

Prior Experience With Concept Mapping

<table>
<thead>
<tr>
<th>Response</th>
<th>Relative Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>50%</td>
</tr>
<tr>
<td>Yes</td>
<td>25%</td>
</tr>
<tr>
<td>Mind mapping</td>
<td>17%</td>
</tr>
<tr>
<td>Something similar</td>
<td>8%</td>
</tr>
</tbody>
</table>

Some of the respondents with prior experience with concept mapping or mind mapping alluded to the perceived complexity of the concepts maps they created in this course. One respondent explained, “I used mind mapping at work. It is different as the concepts do not have to link.” Another respondent said, “We used it in high school but never with this many terms or connected ideas.”

Question two. Question two asked about the perceived benefits of concept mapping. Table 8 shows the frequency distribution of statements for this question. Specifically the question asked, “What do you see as the benefits of concept mapping?” Some individuals stated more than one distinct benefit. For example one response stated, “[Concept mapping] allowed for learning definitions, terms, and connections.” When I coded this response I included it in the counts for the meaning statements making
connections between concepts and learning terms and definitions. For this reason, the total number of key statements listed as perceived benefits of concept mapping is greater than the number of research participants. I believe it is also important to note that if someone chose not to specifically prioritize a certain characteristic of concept mapping as a benefit in response to this question that it does not necessarily imply that they do not feel that it is a benefit to concept mapping. For example, only five people chose to highlight making connections between the concepts as a benefit of concept mapping in response to this question. However later in the questionnaire when they were asked if concept mapping help them to better relate the statistical concepts learned during the semester (Question five), eight out of 12 people answered affirmatively.

Table 8

Perceived Benefits of Concept Mapping

<table>
<thead>
<tr>
<th>Key Statement</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Making connections between concepts</td>
<td>5</td>
</tr>
<tr>
<td>Learning terms and definitions</td>
<td>3</td>
</tr>
<tr>
<td>Useful for reviewing and studying</td>
<td>2</td>
</tr>
<tr>
<td>Allows for visualization of concepts</td>
<td>1</td>
</tr>
<tr>
<td>Easy way to gain points towards grade</td>
<td>1</td>
</tr>
<tr>
<td>Fun to construct</td>
<td>1</td>
</tr>
<tr>
<td>Useful way to organize concepts</td>
<td>1</td>
</tr>
<tr>
<td>May be applied to many topics</td>
<td>1</td>
</tr>
<tr>
<td>No benefits</td>
<td>1</td>
</tr>
</tbody>
</table>
Nearly one half of the respondents emphasized the ability to learn and understand connections between concepts. One respondent explained,

Concept mapping is useful as a study tool to understand the theory behind the ideas and to see how not so obvious concepts fit together based on key phrases. I think that it is great for review and connecting information from week to week in the classroom.

This finding informs Research Question 2a by showing the recognition of many participants of the need to relate statistical concepts and ideas to each other and of the potential for concept mapping to help them make those connections.

Three of the respondents highlighted the usefulness of concept mapping for learning and remembering terms and definitions as a key benefit of concept mapping. This finding informs Research Question 1, “How do students experience the learning of introductory statistical concepts through the use of concept mapping?” in suggesting that students see the potential of concept mapping to aid in learning key terms and definitions. The magnitude of unfamiliar and at times ambiguous terminology is a widespread challenge in the learning of introductory statistics. Other noteworthy benefits identified were the use of concept maps to review and study topics, to organize ideas, and to visualize concepts. Only one person felt no benefit at all to using concept maps.

**Question three.** Question three asked about the difficulties of concept mapping. Table 9 shows the frequency distribution of statements for this question. Six of 12 people felt that connecting concepts and choosing the appropriate linking words were the biggest difficulty of concept mapping. One respondent said, “intricate connections may only be
made after spending a lot of time revisiting the concept maps.” This finding speaks
directly to Research Question 2a. The participants are acknowledging the importance of
making connections between concepts, but the students continue to struggle with that
process in their concept mapping.

Table 9
Perceived Difficulties of Concept Mapping

<table>
<thead>
<tr>
<th>Key Statement</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Making connections between concepts</td>
<td>6</td>
</tr>
<tr>
<td>Time consuming</td>
<td>3</td>
</tr>
<tr>
<td>Hard to plan out</td>
<td>2</td>
</tr>
<tr>
<td>Not helpful for non-visual learners</td>
<td>2</td>
</tr>
<tr>
<td>Not helpful for working with formulas</td>
<td>2</td>
</tr>
<tr>
<td>Hard to adapt to</td>
<td>1</td>
</tr>
<tr>
<td>Not enough examples provided</td>
<td>1</td>
</tr>
<tr>
<td>Not helpful if you do not already understand concepts</td>
<td>1</td>
</tr>
<tr>
<td>None</td>
<td>1</td>
</tr>
</tbody>
</table>

Three of 12 people commented that constructing concept maps is time-consuming.
Several of the responses to this question appear to highlight the fact that half of the
respondents had never been exposed to concept mapping before this class. It is expected
that it would take a while to learn a new technique for representing knowledge. One
respondent said, “Concept maps are hard to plan out,” whereas another commented, “It’s a
hard concept to adapt to, to display the relationships in a visual manner.” There was also
the opinion that the effectiveness of concept mapping depended on the learning style of
the individual. Rather than indicating a specific difficulty of using concept maps, several
respondents made the general statement that concept maps are not useful for visual
learners.

**Question four.** The research participants were fairly evenly split on whether
their concept maps reflected their understanding of the statistical concepts we discussed
during the semester (see Table 10). One third of the respondents felt that their maps did
reflect their understanding well and another third felt their maps did not reflect their
understanding. The remaining third were either not sure or said the maps somewhat
reflected their understanding of the statistical concepts we had discussed during the
semester.

Table 10

*Do Your Concept Maps Accurately Reflect Your Understanding of the Statistical Concepts?*

<table>
<thead>
<tr>
<th>Response</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>4</td>
</tr>
<tr>
<td>No</td>
<td>4</td>
</tr>
<tr>
<td>Somewhat</td>
<td>2</td>
</tr>
<tr>
<td>Not sure</td>
<td>2</td>
</tr>
</tbody>
</table>
One respondent who felt that the maps were a reflection of his or her statistical understanding stated, “I think my concept maps accurately reflect my understanding of the statistical concepts we discussed this semester because the concepts I’ve included in my concept maps are the ones that I’ve chosen to be important to know.” This statement informs Research Question 1 and it suggests this participant experienced concept mapping as a true aid to help organize and represent emerging knowledge. This is in contrast to other participants who indicated that concept maps were either a waste of time or something apart from the learning process used to boost grades or take up time in the classroom. These respondents viewed concept maps as a type of assessment rather than a tool to help organize and deepen knowledge. Research Question 1 was also informed by another respondent’s explanation of why she felt her concept maps were representative of her knowledge. She stated, “Yes, my concept maps were a mess and so was my understanding of stats.” Obviously, this student experienced great frustration in the use of concept mapping to learn introductory statistics.

Several comments appeared to have implications for the degree of confidence that students experienced in using concept mapping. One respondent explained, “One can read the book and notes and squeak out a map, but it doesn’t necessarily reflect your understanding of the material.” This respondent indicated confidence in her procedural abilities to use concept mapping to produce a map that would be acceptable to an evaluator, but was not as confident in her ability to truly organize and display her knowledge. Others displayed their hesitancy as well. One respondent reported, “I’m not sure. I know they helped but don’t know if they reflect my understanding.” Another
participant explained, “Somewhat. It did help me identify keywords and topics. In order to link the words I had to first define them. The process helped my understanding of the concepts.”

The reasons for the negative responses were varied. One respondent said, “No, I was able to connect the ideas well on the map, but practically doing the mathematics of this course was more difficult.” Another respondent said, “Nope. Honestly they were just a hassle to deal with.” Another respondent said, “I think my notes do a better job. Concept maps I have done are just a jumble of thoughts.”

**Question five.** Question five directly addressed Research Question 2a regarding the ability for concept mapping to improve understanding of how concepts are related. Table 11 shows the frequency distribution of responses for this question. Seventy-five percent of the respondents said concept mapping helped them better understand how the statistical concepts were related. One respondent said, “It shows how one topic can be connected to another rather than seeing them as separate concepts and equations.” Another participant said that concept mapping improved understanding of how concepts were related by the process of “constructing the map itself and just seeing how many of the concepts were linked or on each individual map concepts that repeated frequently.” Another respondent agreed,

> Concept mapping has let me see how the concepts are related, especially across the weeks. Looking back, I analyzed how my first concept map contained many keywords in it that I had later created whole concept maps about. I connected them and found many core ideas present in many different concept maps.
Some respondents shared examples of how they felt concept maps helped them to relate concepts. “Concept mapping has helped me better understand how the theoretical concepts are related. [For] example, while constructing concept mappings I’ve noticed connections between normal distribution and inferential statistics, and standard deviation.” A second commenter illustrated the idea by explaining, “we have the correct concepts or terms like population and sample and how they are related.”

Table 11

*Has Concept Mapping Helped You Better Understand How Statistical Concepts Are Related?*

<table>
<thead>
<tr>
<th>Response</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
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<td>8</td>
</tr>
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<td>Somewhat</td>
<td>1</td>
</tr>
<tr>
<td>No</td>
<td>3</td>
</tr>
</tbody>
</table>

One respondent who indicated that concept mapping did not help them understand how the concepts were related felt that the individual’s notes were more helpful in that regard. Another “no” respondent did not address the question directly, instead stating, “Nope. I only did them for the grade; past that I dreaded having to do them.”

**Question six.** Question six directly addressed Research Question 2b regarding the ability for concept mapping to help apply statistical concepts. Table 12 shows the frequency distribution of responses for this question. Seven of the 12 respondents
reported that concept mapping did not help them better apply the concepts we have
studied. Responses included, “I didn’t find it useful in applying the formulas” and “I had
difficulty with the ‘nitty-gritty,’ i.e. which concepts to apply to certain problems.” One
participant elaborated on this idea:

I think I get better at applying concepts by working through problems. Concept
mapping is something that I did after my homework problem sets, and it helps me
better understand stats but not help with the homework, i.e. the application of
stats. But I did use a version of it for “directions” to solve problems.

Table 12

Has Concept Mapping Helped You Better Apply Statistical Concepts?

<table>
<thead>
<tr>
<th>Response</th>
<th>Frequency</th>
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<td>4</td>
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<tr>
<td>No</td>
<td>7</td>
</tr>
<tr>
<td>Not sure</td>
<td>1</td>
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</tbody>
</table>

A participant who felt that concept mapping helped to apply the concepts
concisely stated, “The better I understand something the better I can apply it.” Another
respondent recognized the potential of the concept maps to help apply the concepts, but
shared “overall I did not like the time required to develop the concept map.” The other
students who responded affirmatively to this question linked their ability to apply the
concepts to their ability to see the relatedness of the concepts in their maps.
**Question seven.** Question seven of the questionnaire sought to inform Research Question 1 by exploring the affective component of the students’ experiences of using concept mapping to learn statistical concepts. Table 13 shows the frequency distribution of responses for this question. I felt that it was important to note the directionality of any changes. Five out of 12 participants felt that concept mapping had affected the way they felt about statistics as represented by the comment, “I got a very interesting and useful experience while working at the concept maps.” However, two of these five respondents expressed that using concept mapping changed the way they felt about statistics in a negative way. One respondent said, “it [concept mapping] has made me dislike this class” and the other declared, “Yep. Honestly I hate it more now than I previously did.”

Table 13

*Has Using Concept Mapping Impacted or Changed the Way You Feel About Statistics?*

<table>
<thead>
<tr>
<th>Response</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes—Positive change</td>
<td>3</td>
</tr>
<tr>
<td>Yes—Negative change</td>
<td>2</td>
</tr>
<tr>
<td>No—no change in pre-existing negative feelings</td>
<td>5</td>
</tr>
<tr>
<td>No—no change in pre-existing positive feelings</td>
<td>1</td>
</tr>
<tr>
<td>No—no emotions regarding mathematics</td>
<td>1</td>
</tr>
</tbody>
</table>

Seven of the 12 respondents felt that the use of concept mapping in the class did not affect the way they felt about statistics. Five of those seven commented on having
negative feelings regarding statistics before the beginning of the class that were not affected by their experiences with concept mapping. One respondent noted having positive feelings about statistics coming into the class that were not affected by the use of concept mapping. The final respondent offered an interesting perspective to this question by explaining, “I feel my emotions have little to do with mathematics in general.”

**Question eight.** Question eight provided a forum for the students to share any other thoughts or comments they had on concept mapping. Table 14 shows the frequency distribution of responses for this question. The comments were widely varied but fell into a few general categories.

One category of comments referenced responses to earlier prompts in the questionnaire. For example, respondents highlighted the usefulness of concept maps for making connections, for introducing concepts, and for providing a guide for solving problems. Two participants reiterated that concept maps were a good way to increase their grades in the course, while two others repeated that the use of concept mapping was not helpful and a waste of time.

Another category of responses may be described as recommendations for the use of concept mapping in course in the future. For example, three of the respondents discussed using software to make the concept maps. Most of the participants who used software chose to use CmapTools. One participant said, “it is much easier done using a program, wish I had done that from the beginning.” Two participants indicated that they thought instructor-created or collaborative concept maps may have been more effective. One respondent remarked that it
would have been more helpful if the maps were used during the lecture. Perhaps make one on the board as we go through class to illustrate what we are learning. Then when we work out a problem reference the map as a guide. This will help increase the relevence \(sic\).

A third category of responses recommended not using concept mapping in the course in the future. One commenter shared that “constantly forcing people to do useless busywork does not teach them anything.” Another respondent suggested that concept mapping, while a useful tool, might not be appropriate for use with statistics. A third
respondent in this category felt that additional statistics exercises instead of concept mapping would be more helpful in learning the concepts.

Several themes began to emerge from the analysis of the questionnaires. Students were divided on their overall impressions of concept mapping. Several of them regarded concept maps as helpful in deepening their understanding of statistical concepts and terms. A majority of participants believed that concept mapping helped in making connections between concepts but did not feel that concept mapping affected their ability to apply the concepts in problem-solving situations. Students did recognize the potential for the learning of statistics of concept mapping in conjunction with other active learning strategies, such as collaboration and the use of technology. The analysis also revealed many of the responses to be consistent with the typical characteristics of adult learners. A deeper analysis of the experiences of the key informants, including an analysis of their concept maps, provides even more insight into the themes that have emerged around the research questions. See Appendix G for examples of student concept maps.

**Key Informants**

In addition to the questionnaire and course assignments completed by all students, the key informants were also asked to participate in interviews and reflective journals. The specific evidence submitted by the key informants is presented in Table 15.
Table 15

Key Informants and Their Evidence Submitted

<table>
<thead>
<tr>
<th>Data Source</th>
<th>Geoffrey</th>
<th>Jessica</th>
<th>Anna</th>
<th>Kathy</th>
<th>Matthew</th>
<th>Cole</th>
<th>Carol</th>
<th>Cynthia</th>
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<td>X</td>
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<td>X</td>
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<tr>
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<td>X</td>
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<td>Concept Map 6</td>
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<tr>
<td>Final Interview</td>
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<td></td>
<td></td>
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<td></td>
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<td>X</td>
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<td>Self-Identified Questionnaire in lieu of Final Interview</td>
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<td></td>
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</tr>
</tbody>
</table>

Geoffrey

I was immediately struck by Geoffrey (not his real name) on the first day of the course. He was one of the first students to enter the room and he greeted everyone very respectfully and cheerfully upon their arrival. Geoffrey was an older distinguished gentleman who had already had a successful career and was very involved in his
community. For the next chapter in his life he was focused on starting his own business, a health and wellness center that would serve the underprivileged in a large Midwestern urban setting. Despite his experience and reputation in the community, he felt that having an undergraduate business degree would help him to develop his business. He returned to school through the WEC program while working full time for this reason. He was focused on acquiring the business and critical thinking skills he felt were necessary as well as on having a credential that he felt would give him credibility as he started his business.

Geoffrey lacked confidence in his abilities as a student, particularly in any subject involving mathematics, and expressed his hesitancy regarding the course.

First of all, this course is required in order for [me] to graduate in my major. If I could have gotten around taking this course I would have done it. Secondly, I am intimidated by taking this course, because of my limited ability to perform mathematical equations.

However, Geoffrey did give me the impression that he enjoyed challenges and new opportunities and that he approached them optimistically: “Given the time and study I do believe that I just maybe [sic] able to understand and perform some of the concepts.” He also indicated that he was very willing to learn concept mapping and thought that it would be helpful even though he had never been exposed to it before. Geoffrey expressed his goal for the class as two-fold. “My greatest expectation would be to learn and retain some of the statistical methods and concepts taught to me, as well as passing this course.”
Geoffrey’s concept map for the game of basketball was neatly presented and included all of the provided concepts. He included a few additional concepts, such as zone and motion, and he added descriptive examples of the concepts. He indicated some relationships between concepts with connecting lines, but he did not use linking words nor did his map demonstrate a hierarchy of concepts. Geoffrey chose to represent his proposed business venture in his CM 1.2 concept map (see Figure 4). His concept map showed that he had considered the services that he would provide as well as the business side of the enterprise. The concepts moving down from the main idea of his wellness center included a profit side and a nonprofit side. The profit side node included concepts related to the wellness services he would provide and one node for staffing. The non-profit side of the map focused on organizational concepts such as board of directors and bylaws. A middle flow in the map addressed his target population and included concepts related to the types of health screenings he would offer at the facility. Geoffrey did not include any linking words and, in certain instances, the lines he used to connect the nodes implied relationships that were not entirely accurate. For example, he had a node labeled HIV/AIDS placed directly above a node labeled DIABETES HYPERTENSION. There was a connecting line placed between the two indicating a hierarchy between the concepts. When I asked about this placement, he indicated that those concepts represented two categories of health screenings he envisioned offering. Geoffrey easily articulated the relationships between the various concepts he had included when he discussed his venture, but he indicated that he struggled with connecting the concepts in a tangible fashion on the page.
Geoffrey’s first concept map on statistics (CM 2) included many concepts linked by directional arrows. He still did not include linking words to make the relationships explicit, nor did he demonstrate a consistent progression from broad to specific concepts. Geoffrey started to include linking words in the next concept map assignment (CM 3). He placed a couple of them on arrows but most of them he incorporated into the nodes. For example, he included a node labeled “The variables are” and connected the node by two arrows labeled “quantitative” and “qualitative,” respectively. The “quantitative” node was connected by an arrow leading to another node labeled “includes discrete and
continuous variables.” Even though he wasn’t following the prescribed manner of constructing the concept map, it did appear that Geoffrey was starting to understand the hierarchical organization and role of propositions in concept maps. This map included the majority of the concepts related to the current topic of study. However his map spanned four pages with each page consisting of four or five concepts linked by arrows. These sets of concepts were not linked together by any type of link. On one page he drew a horizontal line effectively separating sets of concepts into two different maps (see Figure 5). This representation directly informed Research Question 2a in that Geoffrey was having difficulty relating the statistical concepts and/or representing their relationships. This map also included some inaccuracies in how the concepts are related in statistics. For example, Geoffrey listed “qualitative variables and” under “quantitative examples.” This representation implies that qualitative variables are a specific instance of quantitative examples, but that is not the case. Rather, the terms quantitative and qualitative refer to two distinct types of data or variables. These terms would have been more accurately placed on the same level of hierarchy. Also, Geoffrey listed “continuous variables” under “discrete variables” again implying an improper hierarchy between the two concepts. They should have been at the same level on the map: both directly under “quantitative examples.” Figure 6 shows this particular segment of Geoffrey’s CM 3 concept map.
Figure 5. Page 1 of Geoffrey’s CM 3 Concept Map
Figure 6. Page 2 of Geoffrey’s CM 3 Concept Map

Geoffrey began to show more progression in making connections between concepts in his fourth concept mapping assignment (CM 4). Geoffrey chose to focus on one specific topic that we had discussed that week: a scatterplot. In this map he better articulated the relationships between the concepts by using linking words on the arrows.
as well as linking words within the nodes. His map demonstrated a clear understanding of what a scatterplot is and how it may be used to assess the relationship between two variables. However, Geoffrey’s remaining three concept maps of the semester showed a return to a listing of concepts with definitions without linking words. We began discussing inferential statistics at this point in the semester, which typically coincides with midterm exams and the beginning of final projects in other courses as well as capstone projects for graduating seniors. It has been my experience in this course that a lot of people begin to feel overwhelmed at this time. I think it is a combination of external pressures and workloads as well as the fact that the topics become a little more complex. We continue to use and build upon the previous concepts as well as to introduce new terms and techniques. These techniques also tend to require more arithmetic and algebraic manipulations than do the earlier techniques. Geoffrey shared around this time that he was impacted by all of these challenges and was mainly focused on trying to learn the new terminology and definitions. The final concept map assignment of the semester required the students to integrate all of the concepts of the semester. Geoffrey instead chose to focus on only the last topic that we had discussed and again this map was a listing of the terms and definitions. Geoffrey’s concept mapping progression throughout the term has direct implications for Research Question 2 through his demonstration and articulation that the concept maps were not directly impacting his ability to relate and apply the concepts he was learning.

I believed that Geoffrey’s experience of learning statistics through the use of concept mapping was affected in several ways. I think it may have added to his burden
of trying to process new concepts and ideas. He stayed optimistic, but he viewed the concept map assignments as something that needed to be done in order to reach a primary goal of the class, which was to pass the course so that he could graduate. I asked him if he felt that working on the problems first would help him identify the important concepts and relationships to represent in the concept map or if organizing the topics first in the concept maps would help him be able to solve the problems. He indicated that the latter was more likely because the concept maps did help him learn the terms and have them as a handy reference. However he still felt that he could not translate that into actually applying those concepts to solve the problems. Ultimately, he reported that he alternated between completing the concept map assignment first or the problem sets first as he didn’t feel like one assignment was necessarily informing the other. His focus on learning the terms and definitions was more for preparing himself for the exam and for being able to recognize these terms in the future when encountering statistical results in his everyday life rather than being able to utilize those concepts for real world data analyses.

Geoffrey indicated at the end of the term that the biggest difficulty of concept mapping for him was connecting the concepts together. Because of this he felt that the concept maps did not accurately reflect his understanding of the statistical concepts and that concept mapping only somewhat helped him understand how the concepts were related. He was certain that concept mapping did not help him better apply the concepts. He felt, though, that using concept maps to keep track of the terms and definitions helped him perform at a passable level at least. Geoffrey did concede that he believed that if he
had more time to devote to the process of concept mapping that it may have been a more effective tool for him. I agree with Geoffrey’s assertions about his use of concept mapping to help him better understand and apply statistics concepts. He did show accurate procedural understanding and some conceptual understanding for selected topics throughout the semester, such as scatterplots for bivariate data. However, the majority of his maps largely included a listing of terms and definitions that he thought represented the particular concepts we had discussed. Neither the propositions he formed in the maps, nor his problem solving in assignments and exams, demonstrated a deep understanding of how the concepts could be integrated with each other for use in statistical analysis.

Geoffrey struggled with statistics concepts and applying statistics throughout the semester, and he did not appear to become any less intimidated by statistics as the semester progressed. In fact, in his final journal entry he said, “statistics I feel is and will continue to intimidate me, because of my limited ability to grasp the statistical formulas.” Geoffrey did not believe that concept mapping substantially impacted his ability to understand statistics other than aiding in memorizing definitions. However, throughout the course, Geoffrey continued to express his belief in the potential of concept mapping. He would share this belief in class discussions, in his journal entries, and even in informal conversations with his classmates that I would overhear while setting up for class in the morning or during breaks. I do believe that Geoffrey saw the potential of concept maps to develop and improve his critical thinking skills. However, I believe he was so intimidated and overwhelmed by the statistics concepts and the problems that
challenged his mathematical abilities that he did not see this as a direct benefit of concept mapping to statistics. He indicated that he thought the use of concept mapping could develop his critical thinking skills for application to his final college course that he was taking the following semester and to the creation of his business plan. As I came to know Geoffrey over the semester and observed his diplomatic and encouraging nature, I sometimes thought that Geoffrey was making these positive statements about concept mapping as a show of support for me and to increase the morale of the class.

Jessica

Jessica was a more reserved student than Geoffrey, but just as amiable. Jessica was a student in the traditional college who was involved in many activities and organizations on campus. She served as an officer of the student athletic advisory committees of both the college and the conference to which the college belonged. She also worked a part-time campus job and played collegiate soccer.

Jessica was extremely anxious about taking the course. She explained that she was nervous and not looking forward to it. She expected “that it would be really hard and that I would struggle with it because I am really bad at math and have been since I started doing math in second grade.” Jessica had used concept mapping in middle school for help in organizing her thoughts to write papers. However, she felt that she did not use them then in as much detail as she would be doing in the statistics course. Jessica’s initial assumption was that the concept maps would help organize her thoughts. Jessica expressed that her learning style was more hands-on: “I need to do things to really like know them.” However, she expressed that “it’s easier to understand kind of like why you
do them the way you do when you use concept maps and how they relate to other things. So I am sure it will help me in that way.”

Jessica’s concept map of the topic of basketball contained all of the concepts I had provided, but no additional concepts and no linking words. She did however organize it in a hierarchical fashion and she used lines to connect the nodes to represent the relationships between the concepts. The concept map representing the topic of her choice was constructed in much the same way as the basketball map. Her main topic was her experience at college. Jessica organized the map into two main parts consisting of the social and the academic aspects of her college life. She included no linking words, instead relying on lines to represent the connections between concepts. She did include cross-links connecting different sides of the map together but without the linking words it was difficult to understand what the relationships were. For example, a node labeled “grades” was listed as part of the academic side of the map, but she also had a line connecting it to “soccer” that was organized under the social side of the map. It would have been interesting to know why or how she was linking soccer with grades. These maps were constructed before our first class meeting when we discussed the basics of concept mapping and the initial concept map assignments.

Jessica began using linking words in her concept maps following this discussion. The linking words in some of these propositions were really other concepts that were related to the concepts that she was connecting, and, therefore, did not meet the conventions of propositions in concept maps. For example, Jessica had nodes labeled “population” and “sample” in her CM 2 concept map, and she attempted to connect each
of these with two other nodes labeled “quantitative” and “qualitative.” Her linking words for these connections were “type of data.” A reproduction of this portion of Jessica’s concept map is shown in Figure 7. The sets of question marks on two of the arrows represent placeholders for the linking words when creating propositions in the CmapTools software. These question marks appear by default when two concepts are connected in the software. Then, the user overwrites these arrows with the desired linking words. Jessica did not change these arrows, but she indicated that she was thinking of the same linking words for these lines that she used for the other two connections. We discussed how an alternative representation on the map may have been to treat “data” as a concept and then to connect these three levels of nodes by the appropriate linking words. Together we developed the following alternative representation seen in Figure 8.

![Figure 7. Reproduction of segment of Jessica’s CM 2 Concept Map](image)
Jessica began using concept mapping software with this assignment. She noted that as she became more experienced with the software that it was easier to develop the maps because she could easily reorganize and move the concepts and links to better represent what she was thinking. As the weeks progressed she often continued to include possible concepts as her linking words, but her organization became more sophisticated. She fairly consistently developed a hierarchy of concepts from broad to more specific and often included cross-links. The significant presence of the links and cross-links in Jessica’s maps speaks to Research Question 2a. Jessica expressed that the benefit of concept mapping for her was “learning how to connect different key concepts and what it is that connects them.” Jessica also felt that concept maps helped her to identify gaps in her knowledge and topics that she didn’t understand as well as others. She explained that

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**Figure 8.** Alternative representation of segment of Jessica’s CM 2 Concept Map
through her propositions she was able to connect the fuzzy ideas to other concepts that she did understand in order to clarify her thoughts.

Some of Jessica’s comments informed Research Question 2b. Jessica stated, “I was able to connect the ideas well on the map, but practically doing the mathematics of this course was more difficult.” Jessica explained that when completing her assignments, she constructed the maps first before completing the problem sets. Then she looked back at the concept maps to see if she had approached the problems correctly. Jessica did not believe that the concept maps helped her to apply the concepts she was learning, but her iterative procedure suggests that she was hoping that it would. When another student shared that he constructed informal small-scale maps that he would use as directions for solving a particular problem, Jessica’s response was “Why didn’t I think of that?”

Jessica believed that her overall experience learning statistics was positively affected by concept mapping by helping her to connect her thoughts. She also favorably viewed the concept mapping assignments because she felt they were more of a low-key assessment than the problems sets. She believed that there was no right or wrong answer in the concept map assignments because it was a reflection of her individual thoughts and ideas. She added that the concept map scores were a “way to boost grades.” However, concept mapping still did not change her attitudes about statistics. “Stats is still a hard math class that I wasn’t very good at.” Even though the use of concept mapping did not appear to increase Jessica’s confidence, I did see evidence of her concept maps helping her understanding. Jessica reported using her concept maps to illuminate particular concepts she did not understand. Then she would revisit those concepts by rereading the
course materials, practicing problems, and asking questions. For example, Jessica expressed uncertainty regarding how sample information was used to draw conclusions about a population. She focused on this idea for a few weeks, and her concept maps from these weeks included many of the same concepts, such as parameter, target number, point estimate, and sample, which are related to this issue. With each map she showed sophistication in how she was relating these concepts which she also demonstrated on her final exam. For example, Jessica was able to successfully implement the appropriate approach to testing a conjecture about a population parameter using given sample data.

Anna

I knew Anna from the previous semester when she was a student in my quantitative methods course. Anna was a graduating senior in the WEC program who had already earned an undergraduate degree from her native country in Eastern Europe. Anna was a serious, but cordial, student and an active participant in the class. She had some previous experience with statistical concepts and she would often lend her perspective during class discussions to help clarify issues for others. Anna contributed a different and enlightening perspective based on her experiences in a different educational system. Anna took a no-nonsense approach to her education and her assignments. She would often comment about her perception of a lack of rigor in the American curriculum. She shared that the workload in her classes in her native country was heavier, and she remarked that the students there completed their assignments without complaint. She was at times mystified by others’ public complaints about the workload, difficulty of the topics, or the expectations for concept mapping.
My recollection of Anna from the prior semester was that she was a strong and dedicated student who met or exceeded all expectations and requirements of the quantitative methods course. I recalled that Anna was comfortable sharing her opinions of the course and she clearly articulated her understanding of the subject matter in the classroom. So, I was looking forward to Anna’s insights for this study. Then midway through the semester she developed some health issues. She only missed one of the seven class sessions; however, there were several instances during the two-week breaks between class meetings when she was unable to study or complete her assignments for a number of days. I believe she was even hospitalized for a period of time during one of these breaks. She started to fall behind in her work at this time, and she missed submitting two problem set assignments and three concept map assignments throughout the term. Anna considered dropping the course or taking an incomplete, but ultimately she decided to stay in the course so that she could graduate as planned. She indicated that her performance to date as well as her comfort level with the subject and her general academic ability gave her confidence that she could successfully complete the course in a timely fashion. I was not able to conduct formal interviews with Anna and she elected not to complete the journal entries, but she still expressed a desire to contribute to the study through informal conversations and email exchanges as well as through class discussions and her assignments.

Anna possessed previous concept mapping experience from her own schooling and through helping her middle-school-aged daughter with a concept mapping assignment. She was not intimidated using concept mapping, and she indicated that
concept maps were very helpful to her because she considered herself a visual learner. Anna’s concept maps of basketball and the topic of her choice demonstrated her familiarity with concept mapping. Her concept maps included appropriate hierarchies, concepts, linking words and propositions. Anna identified the key benefits of concept mapping as being helpful for remembering terms and more fully understanding the concepts. She also credited it as a good organizational tool that helped her to get caught up in the class. The difficulty for Anna was in choosing the right linking words, but she was quite certain that this challenge helped her to better understand how the concepts were related. She described revising her maps several times by changing the placement of the concepts and experimenting with different linking words to form the propositions that she wanted to express. Anna believed her efforts in making these connections explicit helped her in applying the concepts. She described using her propositions as a roadmap to develop a systematic approach to solving the problems.

Anna decided that she would structure her concept map assignments throughout the semester as one integrated map based on the organization of our first class discussion of statistics. Anna’s first concept map for statistical concepts began with the heading “Statistics” which she connected to two nodes to form the propositions, “Statistics consists of Inferential” and “Statistics consists of Descriptive.” The descriptive side of her map was more complex. It included many more levels of hierarchy, more concepts, and more linking words. She decided to include definitions for specific concepts rather than examples as she moved to the lower levels on this side of her map. Anna felt that definitions would be more helpful to her instead of examples as conventionally
recommended for the lowest level hierarchy of the concept map. Anna included some additional detail on the inferential side of the map, which mainly represented her understanding of the general process and purpose of inferential statistics to the degree of specificity that we had discussed in the first class meeting. She indicated her plan to expand on this section of the map for subsequent assignments when we discussed these concepts. Anna expressed that she thought this would be a good way to organically grow the connections between the concepts that she was trying to make throughout the term. I also believe Anna was looking ahead at this point. She knew that the final concept mapping assignment of the semester was to integrate all of the concepts of the semester into a single map or a main map with a series of connected sub maps.

Anna’s final concept map did integrate all of the concepts of the course including the ones explored during the time that she was ill. Anna’s first concept map of statistical concepts and her final map of the semester are shown in Figure 9. Anna acknowledged that her prior familiarity with the statistical concepts made it fairly easy to develop the concept maps. She did indicate that the hierarchical structure of the map challenged her to integrate the concepts with which she had less familiarity. In other words, being forced to put those concepts into the map made her really look at them to see how they related to the concepts that we had discussed earlier in the course. She also indicated that the final concept map helped to prepare her for the exam covering the concepts for which she had missed the class discussions, and it gave her a guide for completing the corresponding problems.
First Statistics Concept Map

(Figure continues)
Figure 9. Anna’s First (CM2) and Final (CM 7) Concept Maps
Anna’s description of her use of her concept maps directly informed Research Question 1. An overarching goal of the introductory statistics course is to develop statistical reasoning above and beyond the learning of distinct statistical concepts and techniques. Although these ideas form the basis of that understanding, the ability to integrate these ideas and apply them to make interpretations based on data are the hallmarks of statistical reasoning. Anna experienced the learning of statistics in this course through concept mapping as a way to more fully develop her statistical reasoning skills. She described and demonstrated how she used concept mapping to help her to identify and understand key concepts and to connect and apply them in practical situations. These findings speak to Research Question 2 as well through Anna’s confirmation that concept mapping appreciably affected her ability to both relate and apply concepts.

Kathy

Kathy was a graduating senior in the WEC program. She worked full time and had family obligations. Kathy was always cheerful and upbeat. She and Geoffrey chatted regularly before class about their other classes and the assignments for this class. Kathy was accommodating and expressed her willingness to help me for my research in any way, but she expressed a lack of confidence in being able to do so because of her perceived math abilities. During the initial interview she described her feelings about taking the course succinctly: “Petrified. Absolutely petrified.” Kathy elaborated, “I put it off until my last semester because I was afraid if I took it sooner I would just quit.”
Kathy stated that her expectation regarding the course was to gain a basic understanding of statistics. She remarked that she didn’t know anything about statistics and that she didn’t do any math regularly, a point I was all too eager to dispute. She stressed that she wanted to get a better understanding about statistics and how it could be used in everyday life. I saw in Kathy some of the common characteristics of adult learners. Kathy was guided by her need to understand the relevancy of what she was learning and the necessity to learn it. Kathy was not eager to take the course because she didn’t see how it was necessary in her life, in addition to the fact that she was anxious about math, but now that she was in the course her goal was to discover the utility of statistics.

Kathy had never used concept mapping before coming into the class and she said she had never even heard of it. After completing a couple of the concept map assignments Kathy’s impression was that concept mapping would help her in learning the definition of the concepts. She explained her process for constructing the concept maps. First she created her parking lot, the list of concepts she wanted to include in her map. She would think about and try to understand what the words meant and then she would try to determine how they were related to one another. Kathy’s concept map in Figure 3 (shown earlier in this chapter) shows her parking lot above the map.

Kathy expressed that creating the concept maps took a lot of time. She commented in the class discussion on the challenge of organizing the concepts appropriately in order to correctly place links and cross-links. Another student in the course shared her process for constructing concept maps. She described using the
suggestion from the first week of class of writing concepts on individual Post-it® notes which she then spread out on her table. She would move the concept maps around in order to form the propositions that she wanted to create. Then she transferred those concepts in the order she had established onto her paper and then connected the concepts with the lines and appropriate linking words to form the propositions. Kathy then recalled this suggestion and she started to do this for her concept maps, but then she tried the CmapTools software and decided that she preferred the software. She created the nodes containing her concepts without any links at first. This process within the software became the parking lot phase of her concept map construction. She then considered the meanings of these concepts and moved them around as she made connections. Then she included the links to form the propositions in her map. As she became more adept at the software Kathy did notice that the amount of time it took her to construct the concept maps decreased.

Kathy’s initial concept maps for the game of basketball and the topic of her choice demonstrated the amount of effort that she put into learning the process of concept mapping at the beginning of the semester. These maps contain appropriate hierarchies, concise propositions, and cross-links. The progression of Kathy’s statistics concept maps throughout the term showed Kathy’s commitment to understanding the concepts of statistics and how they might be useful to her. Her first map was similar to Anna’s map in that she included the general discussion of inferential statistics and then focused her map on descriptive statistics. She included a third concept at the same level of hierarchy as the inferential and descriptive concepts that she labeled data. She then used
cross-links to form propositions between the data concept and concepts on both the descriptive and inferential sides of her map. Kathy’s first map of statistics informed Research Question 2a in that Kathy appeared to be focused on developing “the big picture” from the very beginning of the course.

Kathy continued her focus on making sense of how everything she was learning fit together in her second statistics concept map. The main topic of her map was “measures of center.” She included specific measures of center, including mean, median, and mode, and she formed propositions to represent several characteristics about each of these measures. She connected the concept of mean to a concept labeled deviation to make the proposition “mean difference from is deviation.” Then she connected the deviation concept to a node labeled “variability” by using the linking words “measure of.” The concepts from which she had to choose for this map included three categories of descriptive measures: measures of center, measures of variability, and measures of position. Initially, I was surprised to see the concept of variability placed at the lowest level of her concept map focused on center. I had expected Kathy to include the concept of variability higher up in the map, namely on the same level as the concept of center. My expectation was based on how I had organized the course notes and discussion and on other participants’ concept maps, and perhaps on my own bias of how I think about and represent the relationships between these concepts. But upon reflection of her map and the propositions that she formed, I was struck again by Kathy’s desire to continually fit these new ideas together. So it really came as no surprise then when the main topic of her next concept map was “relationships.” Kathy represented the various ways that
relationships in data can be explored and displayed through various statistical measures and techniques.

Kathy’s next two maps continued this process of trying to find meaningful and usable relationships between the concepts she was learning. Kathy focused her CM 5 concept map on the topic of “random variable.” This map contained fewer concepts than most of her maps, and she quickly moved from somewhat theoretical mathematical ideas about random variables to the normal random variable, a concept that she could readily work with and apply to the interpretation of data. Her next map (CM 6) focused specifically on the normal probability (See Figure 10). Most of her concepts in this map reflected her understanding of the process of applying the normal distribution to the interpretation of data. She connected the concept of “Z-scores” to several other concepts to form propositions that represent steps in the procedure of finding normal probabilities, including “Z-scores standardizes the random variable,” “Z-scores reference the Standard Normal Tables,” and “Z-scores Helps calculate Probability.”

Kathy’s final concept map integrated most of the key concepts we discussed throughout the term, with the exception of a few key concepts related to inferential statistics. This map did not have the consistency of hierarchy that her other maps did but she explained that the number of propositions challenged her organization of the map. Her map did include several cross-links that demonstrated that Kathy had made many connections between concepts discussed all throughout the term. The presence of cross-links in concept maps are indicative of the creation of new knowledge structures
and the integration of key concepts, which in statistics indicate the development of statistical reasoning skills.

![Figure 10. Kathy’s CM 6 Concept Map for Normal Probability](image)

Kathy found the use of concept mapping throughout the semester to help her learn terms and their definitions and to better understand how the concepts were related. Kathy still struggled with the application of the concepts at the end of the semester. She expressed that was her main disappointment with the concept maps was that she did not find them useful for applying the formulas and solving the problems. Kathy explained that she still found math to be scary because she did not feel confident applying the concepts to solve problems. She recommended that concept maps be used in class as a
way to illustrate the concepts during class discussions and as a reference guide when working through problems in class. She stressed that this would increase the relevance of the concept maps to the course.

Matthew

Matthew was a very capable graduating senior in the traditional college who worked both an on-campus and off-campus job. He seemed to have a quirky, generally irreverent, and forthright personality and he was often sarcastic. However, Matthew held his professors and instructors in the highest esteem and always treated them with the utmost respect. These characteristics at times seemed to conflict within Matthew. I had the impression that he alternated between telling me what he thought I wanted to hear and being completely frank about his experiences in the course and with concept mapping. Matthew admitted that he wasn’t fully engaged or committed to the course and that he was “suffering from senioritis.” He was taking the course as a requirement for graduation, and he had already been exposed to introductory statistical concepts through his other coursework. Matthew was confident in his general abilities as a student so he was not nervous about the course.

Matthew was very generous with his time throughout the semester. We had many informal conversations regarding the course and the use of concept mapping in addition to the formal interviews. He did tend to go off topic in the interviews. He expressed his dislike for having to take the course at this point in his college career. He expanded on that by talking about the scheduling challenges of the course and the fact that it was hard to get a spot in the course unless you were an upperclassmen or a nursing major. He also
expressed his frustration with the weekend college format. He was challenged by the four-hour-block of class time early on Saturday mornings, and he thought that the two-week break in between class meetings did not give him the sense of urgency to study or complete his assignments. He noted that his routine for the course was to complete the problem sets and concept mapping assignments late on the Friday night before class the next day. He found the concepts very easy based on his previous courses, so he felt that he could perform at an adequate level with this limited amount of preparation. Matthew expressed that he thought his maps did not accurately represent his understanding of the statistical concepts but he believed it was because of the minimal effort that he put into the maps. He felt that he did not develop much new knowledge, but then he conceded it was because he didn’t put forth much effort.

Matthew indicated that he was familiar with concept mapping and that he had used it before. He described his last experience of using concept mapping in high school geometry when working with if-then statements. His description of those concept maps suggested they were more like flowcharts than concept maps. Concept maps are relationship-oriented and their hierarchy is based on inclusiveness of concepts, progressing from broad, inclusive concepts to specific concepts. Flow charts tend to be process-oriented and their hierarchy is based on a sequence of actions for a given process. Matthew’s description of his concept maps seemed to align more closely with flowcharts because he described mapping out certain steps he would follow in a particular order to analyze the concepts he was exploring. His concept maps for this course did for the most part adhere to the general conventions of concept mapping. He did include concept
hierarchies and accurate propositions. In general, though, Matthew’s maps did appear somewhat haphazardly constructed, and became more so throughout the term, a point that Matthew did not deny.

Matthew demonstrated through his concept maps and through his class discussions and other assessments that he did have a good understanding of the statistics concepts. It is not clear if any of the course activities enhanced the understandings that he brought with him to the course, though. He felt like he could easily represent his understanding of the concepts and how they could be integrated to perform statistical analysis, so he felt that concept maps were irrelevant for helping him to organize and enhance his knowledge. Matthew’s CM3 concept map (shown in Figure 11), focused on “Describing Data Numerically,” was well organized and showed an accurate hierarchy of his concepts. He moved from general categories of numerical measures to specific types of measures, and he included several cross-links showing how these measures were related.

However, as the semester progressed, Matthew reported being busier with other courses and activities and less enthusiastic about the Intro Stats course. Although Matthew was still representing appropriate hierarchies and relationships in his concept maps, the physical representation of these characteristics became less methodical. For example he tended to show his hierarchies through arrows as opposed to the top down hierarchy of a concept map convention. Also, instead of repositioning nodes in order to clearly represent propositions and hierarchies, he would employ dashed lines or arrows that would intersect other arrows (see Figure 12).
Figure 11. Matthew’s CM 3 Concept Map

Figure 12. Matthew’s CM 6 Concept Map
I believe that Matthew’s physical representation of his map structure was illustrative of his feelings about the course. He could clearly articulate a myriad of statistics concepts and how they were related to each other, but he did not feel like his time was well spent on translating that into a well-designed concept map, nor did he feel that his knowledge would be enhanced by that activity. This feeling is evident in his final concept map of the semester (see Figure 13).

Matthew expressed that he experienced the use of concept mapping for the learning of statistics as a “hassle.” He did recognize that concept maps could be helpful
for review and for organizing and relating concepts. However, he viewed concept mapping mainly as a study strategy, and he felt like the study habits he had acquired through the years were more effective for him. Matthew did not characterize himself as a visual learner, and he believed that concept mapping would be appealing to those that were visual learners. Matthew did not feel the need for any new tools to help him learn the material and he expressed being “resistant to a different way of studying.” He explained that as a graduating senior he now had developed what he believed were effective study habits. “It’s hard to teach an old dog new tricks when the old dog has already been trained in a certain way.”

Matthew did not feel like concept mapping could help him apply statistical concepts to real-situations. He believed that the process of concept mapping did not leave room for including a lot of details, which he thought were important in order to apply the concepts. Matthew thought that authentic data analysis situations would be a better use of time for learning how to apply the concepts. He expressed that he would have preferred to do more projects using real data throughout the course to explore the new techniques that we were discussing. He illustrated this idea by proposing that we expand on the class survey that we had done at the beginning of the semester to incorporate the techniques that we discussed throughout the course. The primary use of the survey had been to perform basic descriptive statistics for the data we had collected. He suggested that we could conduct a similar survey of students randomly selected at the dining hall and use this information to make inferences about the population of the
college’s students. He envisioned addressing issues of appropriate sampling and making and testing conjectures regarding the population in this expanded project.

Matthew also believed that my implementation of concept mapping into the course may have been more effective in the traditional class format where there were more frequent and shorter class meetings. Like Kathy, he felt that integrating concept maps into the classroom discussions and working sessions would have been more effective, but he presumed that the time limitations of the weekend college format precluded that possibility.

Matthew expressed that concept mapping was his least favorite part of the class because he viewed it as busywork that wasted his time inside and outside of the classroom. Matthew did indicate that the concept mapping experience did not affect his feelings about statistics. I think his mind was made up on that before the beginning of the class. Matthew felt like he had the appropriate level understanding of statistical concepts that he needed prior to the course, and the course was just a requirement for his graduation.

**Cole**

Cole was a traditional student with junior standing majoring in biology. His demeanor was quiet and laid-back, and he was an exceptional student who was confident in his abilities. Cole participated in fieldwork experiences and was engaged in research projects in biology. Cole had experience reading statistical analyses in scientific papers and using statistics in his own research. He enrolled in this course to get a formal introduction to the statistical concepts he had seen. Cole was excited to learn about
statistics so that he could better understand and apply the concepts within the context of his field and because he enjoyed doing math.

Cole indicated that he was familiar with concept mapping but he had never really used it. He shared using what he considered as something similar to concept mapping when writing a paper. He described the method as a pre-writing suggestion where he placed ideas into bubbles and then connected them in order to organize his thoughts for the paper. Cole quickly came up to speed with the process of concept mapping as evidenced in his CM 1.2 concept map for his first concept mapping assignment (see Figure 14). Cole chose to map the phylogenesis of chordates. His map demonstrated an appropriate hierarchy with examples at the lowest level of the map and appropriate linking words. Cole explained that concept mapping was helpful for him in studying for the statistics course as well as his vertebrate biology course. Cole provided the example of studying the evolutionary development of the chordate phylum. He felt that a traditional way of studying consisting of reading the book and trying to memorize the content was difficult for him, and he felt like he was not could not measure his effectiveness. Cole explained that concept mapping “was a good study tool for me in terms of creating, rather than being you know, like a passive learner . . . I can create something. And that makes me learn better.” Cole also indicated that concept mapping was helpful with the format of the statistics class in that it gave him a way to actively learn and review the concepts during the two-week breaks between class meetings.

Cole identified several key benefits of concept mapping. He felt that concept mapping was a useful study tool to understand ideas and also to see how concepts fit
together. Cole shared that he felt the concept maps took time to do well and that often several revisions were necessary to create the appropriate propositions. Cole chose to construct the concept maps after he completed the problem sets by incorporating and organizing the concepts and techniques that he had used to solve the problems. He then used his maps as a reference for reviewing the topics during the week as well as a guide for solving problems in the future.

Figure 14. Cole’s CM 1.2 Concept Map
Cole believed that concept mapping had a positive effect on his understanding of how the concepts were related. He explained, “looking back, I analyzed how my first concept map contained many keywords in it that I had later created whole concept maps about. I connected them and found many core ideas present in many different concept maps.” Cole’s CM6 concept map demonstrated his ability to accurately connect concepts that we had discussed throughout the term (see Figure 15). Cole’s focus concept was “Sampling Distribution” for this map. He included concepts from the week’s discussion of sampling distributions, and he also included and connected concepts from earlier week’s discussions, including parameters and descriptive measures (from week 1), z-score (from week 2), and standard normal probability (from week 4).

![Figure 15. Cole’s CM 6 Concept Map](image-url)
Cole expressed that concept mapping did not help him with the application of the statistical concepts. Instead he found his ability to apply concepts improved by working through more problems. However, he did mention several times that he used a version of concept maps for directions or guides to help him solve problems. Cole viewed these “mini maps” as he called them as akin to a flowchart detailing the steps for solving the problems and not as “true concept maps” that connected ideas in a specific hierarchy.

Cole indicated that the use of concept mapping may not have deepened his knowledge of statistics. It may be that Cole felt confident with the introductory concepts and techniques, and perhaps felt they were even somewhat simplistic, based on his previous experiences. He recognized the potential for concept mapping to be an effective tool for helping him to connect and organize concepts related to more complex topics in statistics or other areas.

Carol

Carol was a graduating senior in the Weekend College who was taking a full course load while working full time and raising a family. She struck me as being a pragmatic individual who was not easily unsettled. She worked as the Ph.D. coordinator of the biomedical research department of a large world-renowned Midwestern university. She was accustomed to being in a research- and data-driven environment, but she did not feel that statistics had application to her specific work responsibilities or her everyday life. She indicated she was taking this course only to fulfill a graduation requirement for a “non-lab science.” Her professional position caused her to be empathetic to my role as a Ph.D. candidate and she expressed her support of my research endeavors throughout the
semester. She faithfully documented her changing feelings and experiences with concept mapping and the course in her reflection journal entries and, she regularly shared her thoughts in class discussions and in informal conversations with me.

Carol’s response to what she knew about concept mapping at the beginning of the term was “One word: nothing!” Carol later expressed a positive impression of concept mapping after reading the introductory materials on concept mapping and completing her initial maps.

Carol’s first concept map for statistics included the majority of the concepts we had discussed in that first class meeting. She arranged these concepts hierarchically and formed propositions. Her linking words were fairly simplistic and remained that way in her maps throughout the term. Some of the propositions in her maps did not represent correct connections between concepts. For example, Carol included the propositions “variables can be univariate” and “variables can be bivariate” in one of her maps. We discussed that the univariate and bivariate concepts would be more appropriately linked with her concept of data sets to form the propositions “data sets can be univariate” and “data sets can be bivariate.” Carol felt that she had a better understanding of how to relate these concepts after our discussion. However, she asked, “if we don’t have an instructor like you going through our concept maps and pointing out where we went wrong, how will we know?” This question spoke to Research Question 1 in that Carol was experiencing the use of concept mapping for statistics as an assessment tool and not a learning tool. I shared with Carol the perspective that assessments are more than vehicles for assigning grades. Learners and educators may use assessments alike to
identify and resolve misconceptions and areas of confusion. Carol still seemed to struggle with this perspective. In her second journal entry, Carol said, “I am not using the concept mapping to learn the statistics material; I view the concept mapping as part of our assignments, not a learning tool. I haven’t reached that point yet.” In her next journal entry, Carol seemed to be making a bit of progress in that regard. She explained, “It [Concept mapping] helps a bit when I am struggling with the concept. I can stop and review, prioritizing some of the statistics concepts from the larger ideas to the more specific, but I still struggle with the statistics concepts.” In her remaining three journal entries Carol reverted to her earlier impression that, while she was enjoying the concept mapping assignments, they were having no impact on how she was thinking about statistical concepts. She indicated that she was continuing to struggle with the statistics concepts. These statements also indicate that Carol did not see any metacognitive benefits of concept mapping. She did not view concept maps as a way to analyze how she was learning and thinking of these new ideas. Carol often remarked that she felt that concept maps were a “catch 22. You need to know the concepts and relationships to build the map, but if you know the concepts and relationships you don’t need the map to help you learn.” Carol may not have fully appreciated the learning benefits of the act of concept mapping; however, her completed concept maps provided an opportunity for discussion and feedback from me. I was able to discover misconceptions and gaps in her understanding from the concept maps that were not apparent from her problem sets, such as her understanding of “variables” from her CM 2 concept map. Figure 16 shows Carol’s CM 2 concept map with the suggestions I made as we discussed her map.
Figure 16. Carol’s CM 2 Concept Map

Carol was fairly consistent in her remarks that would inform Research Question 2. Carol regularly commented how she was enjoying the concept map assignments because she felt that they were useful for helping to connect ideas. She felt that this characteristic of concept maps had great application, just not in statistics. It appeared that Carol viewed concept maps as a way to demonstrate existing knowledge. “If you don’t understand the concept that you’re mapping, it’s moot.” Carol appreciated the potential for organization that concept maps provided, and felt like she could readily apply this procedure to other topics of which she already had a good understanding, including other courses, such as marketing or corporate finance, and her job requirements.
Carol believed that concept mapping was not helpful for applying concepts in order to solve problems. Near the beginning of the semester Carol did remark that completing the concept map before the problem set helped her in understanding the definitions of the terms she needed to apply in the problems. However as she was required to integrate more concepts in order to appropriately solve problems, she found that the concept maps were no longer impacting her ability to complete her problem sets.

Carol indicated that the use of concept mapping in the course did not affect her attitudes about statistics in any way. She elaborated that her initial feelings were that she did “see the beauty and elegance of statistics, or mathematics in general,” but she didn’t recognize any application of statistics to her work or everyday life. Carol indicated that this impression did not change for her throughout the semester.

Cynthia

Cynthia presented me with my biggest challenge of my initial implementation of concept mapping into my statistics course. Cynthia was a conscientious but anxious Weekend College student with junior standing who was working full time and fulfilling family obligations. Cynthia was enrolled in the statistics course because it was a requirement for her major. She was not looking forward to the class. Her impression was that it required a lot of algebra and she explained that it had been a long time since she had used algebra or had taken a math class. She did indicate that she did some graphing and data analysis in her job but for some reason she distinguished this from her expectation of having to perform what she viewed as formal mathematics in this class.
She expressed a desire to “have a basic understanding of statistics. Nothing too deep, just the basics.”

Cynthia had studied the concept mapping tutorial and completed her initial concept maps of basketball and her self-selected topic before our initial interview. Cynthia began to express her opinions regarding concept maps before I even had a chance to ask the first question of the interview protocol. She said, “Not only am I like, oh I hate this. I’m wasting my time. I still am struggling with propositions, and I’m still struggling with how to put it down on paper.” I responded by offering Cynthia some suggestions for making concept maps easier to construct, such as using Post-it® notes to move around the concepts, using software, or starting with a limited amount of concepts. I also reassured Cynthia that the main goal of the class was for her to develop some statistical literacy. I explained that I strongly believed in the potential of concept mapping to help some students achieve that goal, but that it may not be the case for her. I encouraged her to focus most of her time and energy on the statistical concepts of the course and assured her that her final grade would reflect her understanding of those concepts and not her use of concept maps.

Cynthia indicated that she used mind mapping in her work, but she explained that she did not link the ideas in mind mapping and that was where she was struggling in concept mapping. She felt that with practice she could possibly improve at concept mapping but she expressed that she would rather practice problems instead of focusing on concept mapping. Her initial concept maps demonstrated hierarchical structure, inclusion of key concepts, and clear propositions. They were lacking in complexity, including
examples and cross-links, but still very illustrative of her understanding of her topics.

Figure 17 shows her CM 1.2 concept map describing her home responsibilities.

![Cynthia's CM 1.2 Concept Map](image)

**Figure 17.** Cynthia’s CM 1.2 Concept Map

Her initial attempt for her first map of statistics included the majority of the concepts from our first class discussion (see Figure 18). She made appropriate connections, but her formatting was cumbersome and not reminiscent of the structure she had used in her earlier concept maps. She also expressed on the map her frustration with the process. She then included a second attempt at her map that followed more closely to the conventions of concept mapping structure. At this point, we did discuss her concerns
about the time involved in constructing these maps. Cynthia felt it was the mapping process itself that was causing her confusion and frustration. However, given that the structure was appropriate in her maps of topics with which she was comfortable, I wondered if her frustration was more a result of her confidence level and anxiety regarding statistics.

Figure 18. Cynthia’s CM 2 Concept Map

As the semester progressed, Cynthia’s experience with concept mapping did not improve. She became increasingly concerned with her course grades and performance in the class, and she viewed concept mapping as an additional obligation of the course, one that was hindering her progress. She expressed that she did not feel that concept mapping
was a good fit to her learning style and she would say, “my mind does not work this way.” She felt that she had established study patterns and techniques that worked for her. She resented being “forced” into studying and learning concepts in a way that she perceived as new, unfamiliar, and unsuited to her. She became so frustrated by the process that she spoke to her program counselor about her concerns. We discussed the situation in person and via email several times. I reminded her that she was able to opt out of the study at any time, but she chose not to. She still faithfully completed her journals and regularly communicated her concerns and questions to me. We discussed how the concept maps were required assignments for the course, but I told her midway through the semester that the proportion of her final grade represented by the concept map score was not that significant. Furthermore, she had scored very well on the concept maps she had done so far. Even if she discontinued her concept map assignments it would not substantially impact her grade. Cynthia was a very dedicated and anxious student so I do not think she was willing to stop that assignment even though it was causing her such frustration and interfering with her learning.

Cynthia indicated that her experience with concept mapping caused her to feel even more negatively about statistics than she had before. She felt that her problem sets and her overall course performance suffered due to the time spent on her concept mapping. She believed that her difficulty in connecting the concepts on the map interfered with her ability to relate and apply the statistical concepts. She thought that working on more statistics exercises would have helped improve her understanding of statistics. Similar to Cynthia’s apprehension to explore a new learning strategy, she also
indicated a hesitancy to deviate from the classroom structure and instructional techniques with which she was comfortable.

**Summary**

Analyzing the data compiled from all research participants and examining the in-depth experiences of the key informants revealed some common themes and unique perspectives. The key findings revealed through the analysis of the key informants are summarized in Table 16. The key findings have also been summarized by research question. Table 17 summarizes key findings related to Research Question 1. Key findings related to Research Question 2 are summarized in Table 18.

Most participants agreed that concept maps were helpful in enhancing their understanding of statistical concepts and in integrating those concepts but felt that concept maps were not helpful in improving the application of these concepts to problem-solving. Experiences that were contrary to these general themes provided insight into how concept mapping could be more effectively implemented to address the specific needs of learners, taking into account their statistics anxiety and their perspectives as adult learners. In the next chapter I examine the potential of those themes to answer the research questions of this study as well as their potential to inform future research and practice.
Table 16

*Characteristics and Perceptions of Key Informants*

<table>
<thead>
<tr>
<th>Key Informant</th>
<th>Main Findings</th>
</tr>
</thead>
</table>
| Geoffrey      | Nervous about Stats Intro  
                No prior experience with concept mapping  
                Concept mapping helpful for learning key terms  
                Concept mapping somewhat helpful for making connections, but challenging to connect  
                concepts on map  
                Concept mapping not helpful for applying concepts  
                Concept mapping did not change feelings about statistics—still intimidated by statistics |
| Jessica       | Nervous about Stats Intro  
                Some prior experience with concept mapping  
                Concept mapping helpful in making connections and identifying gaps in knowledge  
                Concept mapping did not change feelings about statistics—still finds statistics difficult |
| Anna          | Not nervous about Stats Intro  
                Prior experience with concept mapping  
                Concept mapping helpful for remembering concepts and making connections, but  
                challenging to choose linking words  
                Concept mapping helpful for applying concepts by integrating concepts and providing  
                guide for problem solving  
                Liked CmapTools software |
| Kathy         | Extremely nervous about Stats Intro  
                No prior concept mapping experience  
                Concept mapping helpful for understanding concepts and making connections, but  
                challenging to represent connections on map  
                Concept mapping not helpful for applying formulas  
                Concept mapping did not change feelings about statistics—still finds statistics scary  
                Liked CmapTools software  
                Wanted to incorporate concept mapping more fully into classroom instruction |
| Matthew       | Not at all nervous about Stats Intro  
                Some prior concept mapping experience  
                Concept mapping somewhat helpful for reviewing concepts and connecting ideas, but  
                did not feel it was a tool that he needed  
                Concept mapping not helpful for applying concepts or problem-solving  
                Wanted to incorporate concept mapping more fully into classroom instruction |

*(table continues)*
Table 16 (continued)

**Characteristics and Perceptions of Key Informants**

<table>
<thead>
<tr>
<th>Key Informant</th>
<th>Main Findings</th>
</tr>
</thead>
</table>
| Cole          | Not at all nervous about Stats Intro  
Some prior concept mapping experience  
Concept mapping a great tool for active learning and for integrating concepts  
Concept mapping is time-consuming to accurately portray hierarchical and relational knowledge  
Concept mapping in a modified form helpful for applying concepts  
Feelings did not change regarding statistics—still found it interesting and useful  
Liked CmapTools software |
| Carol         | Somewhat anxious about Stats Intro  
No prior concept mapping experience  
Concept mapping helpful for organizing concepts, but saw no application to statistics  
Concept mapping helpful for connecting concepts, but not for applying concepts  
Concept mapping viewed as a way to represent existing knowledge, but not as a tool to enhance knowledge  
Concept mapping did not change feelings about statistics—still did not see its utility for her |
| Cynthia       | Nervous about Stats Intro  
No prior concept mapping experience, used mind mapping  
Frustrated by concept mapping; concept mapping hindered her learning of statistics  
Concept mapping not helpful for understanding concepts, making connections, or applying concepts  
Concept mapping changed feelings about statistics by magnifying existing negative attitudes |
Table 17

Summary of Key Findings Related to Research Question 1

<table>
<thead>
<tr>
<th>Key Finding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixed experiences/feelings about using concept maps</td>
</tr>
<tr>
<td>• Some participants demonstrated and/or perceived improved understanding</td>
</tr>
<tr>
<td>• Some participants perceived a negative effect of concept mapping on learning or course experience</td>
</tr>
<tr>
<td>• Some participants perceived no effect of concept mapping on their learning or course experience</td>
</tr>
<tr>
<td>Varying perceptions of concept map activity</td>
</tr>
<tr>
<td>• Learning tool/metacognitive tool, e.g., Jessica, Kathy</td>
</tr>
<tr>
<td>• Separate assessment activity with no effect on learning, e.g., Matthew, Carol</td>
</tr>
<tr>
<td>Varying uses of concept maps</td>
</tr>
<tr>
<td>• Learning terms and definitions, e.g., Geoffrey</td>
</tr>
<tr>
<td>• Relating ideas, e.g., Anna, Kathy, Cole</td>
</tr>
<tr>
<td>• Guide for solving problems, e.g., Anna, Cole</td>
</tr>
<tr>
<td>• Identifying misconceptions/gaps in knowledge, e.g., Jessica</td>
</tr>
<tr>
<td>Dissonance with learning styles/study habits, e.g., Matthew, Cynthia</td>
</tr>
</tbody>
</table>

Table 18

Summary of Key Findings Related to Research Question 2

<table>
<thead>
<tr>
<th>Key Finding</th>
</tr>
</thead>
<tbody>
<tr>
<td>A majority saw potential of concept mapping for relating statistical ideas</td>
</tr>
<tr>
<td>• Integrating concepts is essential to statistical reasoning</td>
</tr>
<tr>
<td>• Making connections between concepts enhanced understanding of concepts, e.g., Kathy</td>
</tr>
<tr>
<td>• Progressive development/revision of maps helped some identify and integrate core ideas across term, e.g., Anna, Cole, Kathy</td>
</tr>
<tr>
<td>• Some participants were challenged by act of constructing propositions</td>
</tr>
<tr>
<td>o Beneficial for some, e.g., Jessica, Anna, Kathy</td>
</tr>
<tr>
<td>o A hindrance for some, e.g., Carol, Cynthia</td>
</tr>
<tr>
<td>A majority felt that concept mapping did not help them apply the concepts for problem solving</td>
</tr>
<tr>
<td>• Understanding and organization of ideas did not help with solving problems, e.g., Jessica, Carol, Cynthia, Geoffrey</td>
</tr>
<tr>
<td>• Those of the opposite opinion tended to have prior experience in concept mapping and used them as “roadmaps,” e.g., Anna, Cole, Matthew</td>
</tr>
</tbody>
</table>
CHAPTER V
CONCLUSIONS AND IMPLICATIONS

This chapter presents a summary of the findings of this study and provides an overview of the conclusions that may be made from this research. Limitations of the study and implications for future research and practice are also discussed.

Summary

The aim of this study was to document the experience of an initial implementation of concept mapping as a learning tool into an introductory statistics course. Students created a succession of concept maps throughout the term to represent their emerging knowledge of introductory statistical concepts. Participants experienced the use of concept mapping for learning introductory statistics in a variety of ways. The use of concept mapping enhanced some participants’ learning, hindered the learning of others, and left no noticeable impression on others. Their experiences were largely intertwined with their characteristics as adult learners. Typical characteristics of adult learners that may have influenced their experience with concept mapping include their previous experiences with learning mathematics and statistics, their learned study habits and strategies, their problem-centered orientation to learning, their perceived relevance of concept mapping to their learning of statistics, and time constraints. The influence of concept mapping on affect was multifaceted as well and was rooted in initial feelings and preconceptions about statistics.

The study also intended to document students’ perceptions of the ability of concept mapping to impact their ability to relate and apply introductory statistical
concepts. Some students perceived and demonstrated an increased ability to understand and explain important statistical concepts. A majority perceived that the relational structures of concept mapping affected their ability to relate and connect statistical ideas, but a majority did not perceive an impact of concept mapping on their ability to apply the statistical concepts for problem-solving or data analysis. Conclusions related to these research questions follow.

**Students’ Experience Using Concept Mapping to Learn Statistics**

Students demonstrated a general willingness to try concept mapping at the beginning of the semester. Participants with past experience with concept mapping saw the potential to organize their knowledge of the new concepts they were anticipating learning. Other participants who were anxious about the course were open to the idea of anything that may help them navigate the maze of statistics. As the term progressed, students experienced the use of concept mapping for learning statistics in varied ways.

**Positive Aspects of Experience**

Students perceived an increased understanding of statistical concepts through the use of concept mapping. Both Geoffrey and Anna relied on their concept maps to help them learn and remember key terms and their definitions. Geoffrey struggled throughout the semester with learning and applying statistical ideas. He turned his focus toward trying to achieve a basic level of statistical literacy. That is, he wanted to be able to understand the statistical information he encountered in his daily life and be able to communicate his reactions to it (Ben-Zvi & Garfield, 2004; Gal, 2002). Anna used her concept maps as a way to keep track of the terms throughout the semester. Her approach
to building her final integrated concept map through smaller sub-maps each week allowed her to maintain a record of the terms that she deemed necessary to learn the concepts each week. This reference then was a great assistance to her when she was trying to get caught up in the class.

Kathy perceived and demonstrated an increased conceptual understanding of key concepts throughout her successive concept maps. For example the concept of variable, or random variable, was present in five out of the six statistics concept maps for Kathy constructed. Each map showed an increased sophistication of Kathy’s understanding of the role of variables in statistics. Carol held a more cyclical view of how concept mapping affected her understanding of statistical concepts. Rather than helping her to learn and understand the concepts, Carol felt that she could not do the concept maps well if she did not already understand the concepts. In this way, Carol experienced concept maps not as a learning tool but as an assessment of her understanding of statistics.

The findings suggest that the students were experiencing metacognitive benefits of concept mapping. Jessica used her concept maps to help her identify her gaps in knowledge and to identify areas she need to review. This process helped her to reveal new understandings and relationships between concepts. This monitoring of comprehension and evaluation of the thinking process are key components of metacognition (Bauer, 2014). Another study participant affirmed the metacognitive benefits of concept mapping, explaining, “I think, my concept maps accurately reflect my understanding of the statistical concepts we’ve discussed this semester because the
concepts I’ve included in my concept maps are the ones that I’ve chosen to be important to know.”

Another observed benefit associated with the introduction of concept mapping in this course was the perceived value of concept mapping as a learning tool in other disciplines or milieus (Afamasaga-Fuata’i, 2009; Chiou, 2008). Carol felt that she could implement concept mapping in her professional life as way to represent, explain, and monitor her work responsibilities. Geoffrey also thought that concept mapping could be adapted to his professional interests. He believed that the use of concept mapping would help him in establishing his business plan. Furthermore, Geoffrey believed that the critical thinking skills that concept mapping engendered would be an advantage to him in his business venture. Cole and Jessica endorsed the use of concept mapping in other courses such science. They emphasized the ability to represent evolutionary and other biological processes through the use of concept maps.

Although I was not looking, in particular, at concept maps and collaboration, I did notice that students were impacted by the level of collaboration incorporated into the concept mapping process. Students benefited from the discussions about the concept maps that they had made. They learned how their colleagues were making sense of the statistical concepts by sharing and discussing their maps. This collaboration has the potential to improve conceptual understanding and attitudes regarding statistics (Tishkovskaya & Lancaster, 2012). They also shared insights and advice regarding the process of concept mapping itself. Some participants felt that a fuller and more effective experience with concept mapping could have been achieved through collaboratively
building the maps. This combination of active learning strategies more fully fosters a
constructivist approach to instruction and learning and can aid in construction of key
concepts (Roth & Roychoudhury, 1994).

The data suggest that those students who adapted well to using concept mapping
in the course may have experienced more benefits than those who were not comfortable
using the technique. Some of the students, such as Jessica, Cole, and Anna, who were
observed to be comfortable with the concept mapping technique as evidenced by their
discussion of their previous and current experiences with concept mapping as well as the
sophistication of their concept maps, indicated that concept maps helped their ability to
understand statistical concepts and to connect statistical ideas. Jessica did not experience
an overall increase in her confidence in her ability to understand or use statistics.
However, she did note that the process of connecting ideas in her concept maps helped to
clarify her thoughts and identify misconceptions about statistical concepts. Although
Cole believed that concept mapping may not have increased his previous knowledge of
statistics concepts, he did feel that his maps were beneficial in helping him better connect
these ideas and to identify the core ideas of the course by reviewing his maps throughout
the term. Anna, like Cole, demonstrated a clear understanding of how to construct
collect maps and an appreciation of them. She felt that the challenge of constructing
appropriate propositions helped her to better connect the concepts of the course. She also
credited concept maps with helping her better organize and understand the concepts
needed to solve problems. These findings stand in contrast to the experiences of others.
For example, Matthew, Cynthia, and Carol, who did not embrace concept mapping for
various reasons that were documented previously, did not experience an increased understanding of statistical concepts through their use of concept maps.

The students that adapted well to using concept mapping in the course did not necessarily implement the technique as conventionally prescribed. Instead they adapted its use in ways that integrated into their study habits and ways of learning new material and based on their previous knowledge and experience. Cole viewed his “mini-maps” as a departure from the formal maps he developed to represent his understanding of introductory statistical concepts, but he believed that this modification would assist him in learning how to approach and solve problems in specific scenarios. Geoffrey and Carol emphasized the brief, organizational component of concept maps over the propositional attribute as a way to organize and memorize the unfamiliar terms they were learning.

Negative Aspects of Experience

Some students were negatively impacted by the use of concept mapping in the statistics course. Students expressed views of concept mapping as a waste of time inside and outside of the classroom. Cynthia, for example, felt that her time outside of the classroom would have been better spent practicing statistical exercises and applying her usual methods of studying. Although Matthew’s perspective on statistics was not adversely affected by the concept mapping experience, his view of concept mapping as busywork did negatively influence the way he felt about this particular class. He was not motivated to attend class or to extend more than a minimal level of effort on his assignments.
Cynthia’s frustration with concept mapping hindered her learning process, which impacted both her ability to understand statistics and her feelings about statistics. Cynthia demonstrated resistance to a new learning strategy in many of the traditional ways (Seidel & Tanner, 2013). She expressed her frustration and displeasure with concept mapping to me and to administration frequently. Cynthia reluctantly complied with the requirements of the course by completing her concept map assignments. In addition, she ardently defended her learning style and insisted it was not aligned with the concept mapping strategy. Cynthia may have been experiencing resistance to active learning in general as she did regularly express her comfort with the conventional instructional and learning strategies to which she was accustomed.

Other students also viewed concept mapping in dissonance with their learning style, study habits, or time constraints. These students also demonstrated student resistance in some form. Matthew provided excuses for his performance and participation. He cited his employment obligations, his general lack of motivation because of his senior status, and his perceived comfort and ability with statistics as reasons to not commit himself to the concept mapping strategy. Other participants provided similar excuses, avoided class discussions on concept mapping, did not complete some concept mapping assignments, or complied reluctantly or at a minimal level. The reasons for this resistance may include the amount of concept map training, the level of familiarity and prior exposure to active learning strategies, the lack of time to fully engage in concept mapping, and the perceived lack of incentive to fully participate in the learning strategy (Seidel & Tanner, 2013).
In not adapting to the use of concept mapping as a learning strategy, these students did personify characteristics of adult learners. They demonstrated responsibility for their own learning as they examined the process of concept mapping to determine if they could integrate it into their current learning patterns. If they determined that it was not impacting their learning of statistics, they fulfilled the responsibilities of the course while still relying on their learned study habits to make sense of the new material. In addition, some students looked for ways to make concept mapping relevant to their educational or everyday lives. Some (although not all) also chose to focus on strategies for problem-solving that may or may not have included concept mapping.

**Neutral Aspects of Experience**

Some students expressed the use of concept maps as having no substantial influence on their experience of learning statistics. They viewed it as neither a help nor a detriment to their learning process. One study participant indicated that concept maps were very easy to complete and he acknowledged the ability of concept mapping to connect and relate ideas, but he still felt his understanding of statistics was not impacted in any way by the use of concept mapping. There may be several explanations for this feeling. This individual had expressed prior negative attitudes regarding statistics that may be resistant to a brief exposure to any alternative learning strategy. Also, this ambivalence may be representative of the level of engagement that students had with the concept mapping tool. Students accustomed to a conventional method of teaching or learning may not be comfortable with new approaches or they may not perceive the benefit of the additional time and effort required to implement the new approach (Seidel
& Tanner, 2013). Other students, including Carol and Matthew, viewed the concept maps as assessments. They approached concept mapping as the creation of a product for external assessment rather than as a strategy for meaningful learning or metacognition. Students as Carol and Matthew might, therefore, be in the negative column, viewing concept maps as just an extra “add-on” and not particularly helpful.

Concept Mapping and Relating Statistical Concepts

Connecting statistical concepts was viewed as both a key benefit and a key challenge to the use of concept mapping in learning statistics. Integrating ideas and connecting concepts are challenging aspects of reasoning statistically and interpreting data (Gal, 2002).

Benefits

Less than half of the participants chose to specifically list connecting and relating concepts as a perceived benefit of concept mapping in response to question two of the questionnaire. At the same time, eight of the 12 participants said that concept mapping helped them better understand how concepts were related in response to that direct question (question five of the questionnaire). These students experienced the ability to connect new ideas to their existing knowledge through concept mapping. They perceived this integration of concepts and contexts as the beginning of statistical literacy (Gal, 2002).

Some students who expressed that they were struggling with learning the statistical concepts perceived the required connections in concept mapping as helping them to better understand the concepts. Kathy’s understanding of the concepts was
enhanced by the process of making connections within the map. She felt like she had to carefully consider and define the terms in order to link them, and this process helped her to achieve a deeper understanding of the topics.

Some students perceived that their ability to holistically relate the ideas throughout the semester was impacted by their use of concept mapping. Progressive mapping allowed them to deepen understandings and more meaningfully integrate their knowledge (Afamasaga-Fuata’i, 2009). Cole recognized how his maps built upon themselves across the weeks, and he found himself being able to clearly identify and differentiate core ideas across the varied topics of the semester. Kathy experienced being able to better integrate statistical concepts metacognitively. As she reviewed her weekly maps in order to develop her final integrated concept map of the term, she noticed keywords that were present in many of her maps and she noticed that those keywords connected with a variety of other concepts based on the specific topic of a particular map.

**Challenges**

Several students expressed difficulty with connecting concepts in their maps and some indicated that they believed their understanding of the statistical concepts was not accurately portrayed in their concept maps because of this challenge. Building propositions in concept mapping is a challenging skill that is improved with practice. The students’ relative inexperience with concept mapping may certainly have attributed to this phenomena (Cravalho, 2010; Lavigne, 2005). Cynthia perceived that her inability to understand and relate statistical concepts was a result of being required to complete the concept mapping assignments. She reported such difficulty with properly organizing her
maps and creating propositions that she felt her learning of statistics suffered due to the time spent on her concept maps and because of her frustration with the technique. Undoubtedly, this had an effect on Cynthia’s learning. However, at the beginning of the term, Cynthia entered the class indicating anxiety regarding statistics and concerns about having to perform mathematics. These attitudes and understanding regarding statistics could be a contributing factor to the difficulties she experienced in constructing her concept maps. It is possible that Cynthia’s insufficient understanding of the connections between statistical concepts made it challenging for her to map the structures (Lavigne et al., 2008). Given the nature of qualitative human subjects research, the nature of any causal relationship cannot be inferred.

Beliefs about statistics are linked with performance and attitudes about statistics. A perception that statistics is the use of discrete formulas and procedures as opposed to a relational network of ideas and techniques will encourage an individual to focus on applying those formulas and procedures in a distinct and separate manner (Gal & Ginsburg, 1994). Furthermore, learning strategies are most effective when they are aligned with the nature of the subject (Kinchin, 2014). Because concept mapping places such a strong emphasis on relationships, it may be perceived as being most appropriate for disciplines that are highly relational. Individuals who did not see the relational aspect of statistics did not see the application of concept mapping to statistics as beneficial. Matthew and Carol did not recognize the need to connect concepts in order to reason statistically (Ben-Zvi & Garfield, 2004). Matthew did not view statistics as a network of interrelated concepts and ideas; rather, he identified statistics as a set of formulas and
mathematical procedures to be applied in distinct and prescribed situations. He viewed other subjects such as psychology and biology as being much more relational. He grouped statistics with mathematics and described them both as being very formulaic and application-driven. Carol also viewed statistics as an enumeration of details and the application of step-by-step procedures. She did not view using statistics as a way to “get the big picture.” Even though Carol and Matthew acknowledged the potential of concept mapping to represent relationships between concepts, they did not see its application to statistics for this purpose.

**Concept Mapping and Applying Statistical Concepts**

Seven of the 12 participants perceived no influence of the use of concept mapping on their ability to apply statistical concepts according to the questionnaire data. Some students expressed preferring statistical exercises or projects as methods for helping them to better apply concepts. Most students did not view statistics as a discipline separate from mathematics. Therefore, they tended to rely on their previous methods for learning mathematics to which they were already accustomed. Their perceived disconnect between concept mapping and problem solving may also be attributed to their level of experience with concept mapping. It does take a while to become proficient in building sophisticated knowledge structures in concept maps, but then these structures may be beneficial for developing a framework to solve problems (Kamble & Tembe, 2013). A study participant acknowledged this potential by explaining, “The better I understand something the better I can apply it.”
Students that found concept mapping helpful in applying statistical concepts indicated that the organizational benefits of concept mapping provided them a roadmap or a set of directions on how to apply appropriate concepts to solving problems. The fact that these maps were student-generated have the potential to affect the individual’s problem solving abilities because the learners were actively integrating their individual knowledge structures (Lee & Nelson, 2005). Cole and Anna routinely used some version of their concept maps to assist in solving problems. Even Matthew felt that he could reference his concept maps to be reminded of certain concepts that he could use to solve problems.

**Limitations of the Study**

The selection and participation level of the key informants may be considered a limitation of the study. Nearly 90% of the class elected to be study participants and over half of the class agreed to be key informants. Perhaps I should have prescreened for previous experience with concept mapping, openness to attempt new approaches, and the time and commitment to complete all data sources for the study. No one key informant completed every piece of requested evidence. However, I am reminded that my participants embody the typical population for this course. They are adult learners who have previous habits and experiences, pressing time commitments, and emergencies that arise, all of which inform the case, which was the experience of implementing concept mapping into this particular introductory statistics course. Although the results of this study are not generalizable due to the small sample size, the smaller sample focus allowed a deeper qualitative analysis than a more generalizable study would allow. In
addition, the weekend college setting, which was the particular context for this case, has distinct characteristics, and the findings from this context may be different from those of other contexts, such as a more traditional class format. Quantitative research emphasizes controlling variables so that specific effects may be analyzed and conclusions and generalizations drawn from them. However, in qualitative case study research, “our first obligation is to understand this one case . . . The first criterion should be to maximize what we can learn” (Stake, 1995, p. 4).

The potential for pro-teacher bias is a limitation of the study given that the research participants were recruited on a voluntary basis and I was the instructor of the course. I attempted to avoid this by having students not reveal their study participant status until after the end of the term. A disadvantage was that key informants had to be identified earlier so that I was able to conduct interviews. I did explain, as did the college administration, that participating or not participating would have no impact on their grade, support from me, or other educational opportunities that might arise. I stated this verbally and in the consent documents. In reflecting on this issue I can say that I was less concerned with this possibility with my population of students than I may have been in a different environment, such as K–12. Most of these individuals are confident working adults. Furthermore, they pay a considerable amount of money for their education and tend to be somewhat demanding, although respectfully so, of the faculty. They tend to be comfortable putting their needs first and expecting the full integrity and support of the faculty. I do not think the students would have felt overly compelled to please me to obtain a certain grade or my instructional support. Also, some of the more critical
comments made throughout the term regarding the use of concept mapping appear to support this belief.

Another limitation to the study may be the time constraints I felt in establishing deep connections with the students and observing significant evidence. The fact that I met with the students only a limited number of times, including seven course meetings and a few interview and office hour sessions, made it somewhat difficult to establish rapport with them. Although the technology has somewhat eased this burden, and I did try to communicate them with them regularly as a class through the learning management system and individually through private messaging, email, or phone conversations, I still felt that I was not able to develop the relationships or comfort level that I could have in a more traditional class setting where I would have seen and interacted with the students on a daily basis for an extended period of time. Another challenge of the limited contact time is the pace we must maintain in class. Each four-hour block of class time must cover material equivalent to the content of a two-week period, or four to six class sessions, in a traditional setting. We need time to review and address questions from the previous week; examine and explore new material through course discussions and demonstrations, computer work, and problem-solving sessions; and conduct formal assessments. This did not leave a lot of class time to discuss the students’ concept mapping.

Another potential limitation of the study was the composition of the students of this particular weekend college class. Whereas there are typically one or two traditional students in my course, this class was fairly evenly split between traditional students and
weekend college students. This makeup seemed to cause some intimidation. The adults were intimidated by the perceived understanding and technological savvy of the traditional students whereas the traditional students were intimidated by the real world experience of the adults. This dissonance often seemed to stilt the conversations regarding concept mapping. Another split that caused similar dissonance was the disparity between the more confident upperclassman who were just taking the course at this time due to scheduling difficulties versus the ones who were taking it at this time because they had delayed enrolling for as long as they could.

The amount of concept map training the students had may be considered another limitation of the study. The students were not fully comfortable with the technique, and they were assimilating themselves to concept mapping at the same time that they were trying to learn the statistical concepts of the course. Given their novice status, their concept maps may not accurately represent their understanding of the material. Also they may not have been able to take full advantage of the technique’s potential as a cognitive tool to enhance meaning and integrate their knowledge.

Another limitation of the study may be the fact that concept mapping was a required assignment. Some students viewed it primarily as an additional assessment for the course. They focused on producing “the right answer” or a final product instead of on the process of knowledge integration and meaningful learning through concept mapping. This may have denied them the freedom to flexibly work with the tool and to use it to augment and promote their understanding of the concepts. A related limitation of the study may be the fact that although concept mapping was a required assignment, it only
counted for 15% of their course grade. Furthermore, concept mapping was not included in the two exams. The fact that the questions on the exams more closely resembled the problem set questions may have suggested to some students that concept mapping was not as important a component of the class as the problem sets and exams. That may be why some participants felt that concept mapping was a waste of their time. Also, given that some of the students viewed the Intro Stats course as a mathematics class, they may have weighted exercises involving problem-solving and calculations more heavily than exercises, such as the concept mapping assignments, that focused on conceptual understanding.

A further limitation of the study is the complexity of the concept model that was adopted, although I used the one that has been suggested by Novak who developed concept maps (Novak & Cañas, 2008; Novak & Gowin, 1984).

**Implications for Future Research**

We need a more comprehensive understanding of the benefits and challenges of incorporating concept mapping into the learning of undergraduate introductory statistics. Data from the study indicate that concept mapping was beneficial for students who were comfortable with the technique in helping them learn statistical concepts and make connections between them. One potential implication is to study one or two students who embraced the use of concept mapping in statistics to create an in-depth portrait of how these students incorporated concept mapping into their learning of the discipline. It would be interesting to closely examine how these students demonstrate their conceptual understanding by looking at how they reveal the relationships between concepts.
(Lavigne, 2005). Also, this research focus could reveal ways that these students use concept maps metacognitively to help them identify misconceptions or gaps in their knowledge (Schau & Mattern, 1997).

Another possible direction for this research would be to look more closely at the relationship between concept mapping and affect. The data suggest that the frustration that accompanied learning concept maps while also learning statistics may have increased the negative attitudes about statistics. One possible line of inquiry extending from these findings might include focusing on students who have experience and are comfortable with concept mapping and who identify as having anxiety or negative attitudes regarding statistics. It would be interesting to see how the use of concept mapping may affect these particular students’ perceptions of their anxiety and attitudes about statistics.

The data also suggest that perhaps the time it took for students to learn how to construct concepts maps and to become comfortable with them took away time that they would have had to focus on developing meaningful understandings of the statistical concepts and to practice applying these concepts. One possible approach is to implement a longitudinal study where one or two individuals are followed through several statistics courses or courses in other disciplines that use statistical techniques while at the same time continuing to practice concept mapping. Through this study, we may discover the effects over time of the ability of their use of concept maps to influence both their knowledge structures and their attitudes about statistics.

Concept mapping is widely recognized as a powerful tool for enhancing meaningful learning in mathematics and statistics (Afamasaga-Fuata‘i, 2009; Lavigne,
2005; Lee & Nelson, 2005). However, the use of concept mapping remains more prevalent in other disciplines than in statistics. It may be informative to investigate this phenomenon. A large-scale survey would be valuable to determine the extent of concept mapping use in undergraduate introductory statistics courses. Questions would focus on the familiarity and comfort level of introductory statistics instructors with regard to concept mapping. It would be interesting to learn if instructors have used them in their classes, and, if so, to what extent and in what ways. We would also be able to explore their impressions of the effectiveness and challenges of concept mapping and what the instructors see as the barriers to implementing concept mapping.

An extension of the research proposed above would be to identify instructors from this survey who are effectively implementing concept mapping in their classrooms. A multi-case study, where the settings vary by modality of concept map use, such as collaborative use, expert maps, technology and software, assessment, and as a learning tool, or by classroom setting, such as a more traditional undergraduate classroom setting, adult learning environment, and even online courses, would provide valuable insight into the effective uses of concept mapping in introductory statistics courses.

**Implications for Practice**

The findings of this study suggest the potential of concept mapping to improve the experience of learning introductory statistics concepts. Concept mapping has the ability to help some students relate and connect statistical concepts, which can aid in the development of statistical reasoning. While the data in the study suggest that students did not see the potential of concept mapping to help them apply the concepts they were
learning, a more integrated use of concept mapping and problem solving may ultimately have the effect of helping students to solve problems through the visualization of the knowledge structures needed for problem solving (Kamble & Tempe, 2013; Lee & Nelson, 2005).

This integration of concept mapping and problem solving could be implemented in individual and group settings. Students could be asked to solve homework problems while simultaneously constructing the concept maps. Likewise, concept maps could be constructed collaboratively in conjunction with a group problem solving activity. As a particular concept or idea is used in the problem solving process, the node for that concept may be created in the map. The next step or idea in the problem solving process would then be connected in the concept map and a proposition would be formed. In this way, the concept map would be organized as it relates to the iterations of the problem solving process.

More opportunities and encouragement for revision of concept maps would enhance their effectiveness and utility as well. Participants noted that they needed to make several revisions to their maps to accurately represent their understanding of how the concepts were related. Also, they noted revising connections over time as they attempted to assimilate new concepts into their existing maps. Providing students with multiple opportunities for revision of their concept maps may help students to distinguish concepts, to identify and address gaps in knowledge and misconceptions, and to integrate knowledge (Schwendimann, 2011).
Some students commented on their belief that concept mapping could be helpful to developing their understanding of statistical concepts. However, they felt overwhelmed by the process of constructing concept maps on their own and did not have the confidence or feel like they had the appropriate knowledge to critique and assess their own maps. Concept mapping approached in a collaborative way may alleviate these concerns. Students would have the ability to defend their concept maps and compare them with others. They could also use concept maps created by the instructor or the group to provide the structural knowledge necessary to solve problems.

Another way to lessen the perceived burden of concept mapping may be through the more extensive use of technology to construct concept maps. Students reacted well to the use of software to construct their concept maps. Using concept mapping software makes it easier to move around concepts and experiment with different propositions and hierarchical structures. This process also has the cognitive effects of creating and reinforcing those connections. The ease of the software also makes revisions less daunting. Concept maps created in software may also be shared easily via electronic communication thus allowing for collaborative input and more frequent feedback from the instructor. An important consideration, however, is that a certain segment of the adult learning population is still on the cusp of embracing technology. Some may view using technology or having to learn new software as an added burden to their learning process in much the same way as some individuals viewed learning concept mapping.

More concept map training may be advisable. Respondents indicated a lack of confidence in their maps’ abilities to represent their understanding. Many of the maps
did exhibit shortcomings in terms of the requisites structures of concept maps.

“Becoming a proficient concept mapper takes time and practice and should start much earlier in a student’s career and in a range of different contexts” (Schwendimann, 2015, p. 74). This is a difficult proposition, though, given the stage of life this population and the limited time and energy adult students have to devote to their educational pursuits. An orchestrated effort between administration and faculty in the adult learning program is necessary to help remediate this issue. Concept mapping could be incorporated into study skills and time management workshops offered by the institution.

The introduction of a new learning or instructional strategy into a classroom should be carefully considered with respect to the developmental age of the participants. Adult students typically have limited time and are comfortable in their established ways of approaching learning. In addition, as these students are more likely to embrace learning that has personal relevance, any new strategy should be deliberately introduced and its purposes well explained.

The findings of the study also suggest fostering the use of multiple strategies for statistics learning. The mixed experiences and feelings expressed by the participants regarding the use of concept mapping for learning statistics may be due to the fact that individuals learn statistics in different ways. Some of the participants highlighted their particular learning styles as either being consistent or inconsistent with concept mapping. For example, Jessica, Anna, and Matthew expressed that they felt concept mapping is a strategy conducive to visual learners. Providing differentiated learning opportunities, of
which concept mapping may be one particular strategy, may be a way of addressing the specific and varied needs of statistics learners.

**Conclusion**

Moustakas (1990) envisioned heuristic inquiry as a systematic approach to examining human experience

That begins with a question or problem which the researcher seeks to illuminate or answer. The question is one that has been a personal challenge and puzzlement in the search to understand one’s self and the world in which one lives. (p. 15)

That question for me was how to enhance students’ learning of introductory statistical concepts and potentially improve their experience in a class that not only challenges many people but that many individuals dread and go to great lengths to avoid.

My experience in implementing concept mapping as a learning tool into my introductory statistics class for the first time has been both and enlightening and challenging. I have learned that concept mapping, or any learning or instructional tool, is not a one-size-fits-all solution. However concept mapping in some form has potential to enhance the learning of introductory statistics concepts. That form could be as a learning strategy for some or an instructional strategy used in the classroom in the form of expert maps, advance organizers, or collaborative exercises.

Over the years, I have continued to implement new ideas in the classroom, such as different technologies, simulations, hands-on experiments, the use of real and realistic data, collaborative problem-solving, and projects. I have informally gauged the success of these techniques through traditional methods of assessment, informal observations,
anecdotal analysis, and feedback through course evaluations. Although the process of data collection and analysis was time-consuming for this study, I see the benefits of rigorously and systematically analyzing the effects of these strategies. I also see that not only does my attention need to be focused on the effectiveness of these instructional strategies, but I also need to analyze and attempt to facilitate the learning that happens outside of the classroom. I can do this by continuing to espouse the potential of concept mapping and modeling its use in my course.

At the beginning of each semester I tell my students in introductory statistics that at the end of the term they will have a statistical toolbox. They will have accumulated a set of tools—terms, concepts, techniques, and formulas—to have at their disposal to help them analyze and interpret data. Based on their data, context, and goals for analysis, they will have the knowledge and confidence to choose the right tool for the job and be able to use it appropriately. As an educator, I, too, have a toolbox—a set of strategies to offer my students in order to enhance their learning. Implementing concept mapping into my introductory statistics course has given me one more tool to add to my educator’s toolbox.

Finally, my hope is that my study may inform statistics educators at all levels as well as educators of all disciplines in adult learning environments. The key to developing statistical literacy and statistical reasoning in individuals is helping them to see “the big picture.” That is, they need to be able to integrate and apply statistical concepts and techniques in order to make sense of the data they encounter in their daily lives. These skills must begin to be developed at an early age and continue through all levels of
schooling. If concept mapping is implemented at the earliest stages as well, students may have the opportunity to incorporate this learning tool as they are developing their habits for learning. They may come to see concept mapping as an organic way to grow and integrate their knowledge of statistical ideas. It is also my hope that the study may remind educators of adult students that they need to be attuned to the experiences, breadth of knowledge, and dispositions that their students bring to the classroom. However, they should not be hesitant to attempt new learning and instructional strategies in a deliberate and transparent way.
APPENDICES
APPENDIX A

INTRO STATS SYLLABUS
Appendix A

Intro Stats Syllabus

<table>
<thead>
<tr>
<th>Intro Stats</th>
<th>Spring, 2012</th>
</tr>
</thead>
</table>

| Instructor: | Dawn-Marie Trehan | E-mail: | trehandm@xxx.xxx |
| Phone:      | (330) xxx-xxxx  | Fax:    | (330) xxx-xxxx  |
| Office Hours: | by appointment  |
| Phone Office Hours: | Wednesdays, 6 pm – 8 pm |
| Class Sessions: | January 14, 21, February 4, 18, March 3, 17, 31, 8:00 am – 12:00 pm |
| Class Location: | Hall 202  |

Course Description

An introduction to the science of collecting, tabulating, summarizing, and interpreting data. Both descriptive and inferential statistics are studied. Descriptive topics include levels of measurement, measurement of central tendency and dispersion, the normal and binomial distributions, and correlation. Inferential topics include hypothesis testing, interval estimation, regression analysis, and the use of nonparametric methods.

Course Objective

There is much information in real life that may be analyzed using statistical techniques. The use of statistics helps us make informed, objective decisions. The goals of this course include introduction to the fundamentals and applications of these techniques for many other fields of study. Comfort with and knowledge of these techniques will support research and study in other disciplines. Other important objectives are the development of critical thinking, analytical reasoning, and organization of thoughts and processes in both verbal and written form. Furthermore, it is hoped that the achievement of these goals will lead to the demystifying of
statistical and quantitative techniques and an understanding of their relevance and ease of use in everyday life.

Specific concepts and tools that you should be able to apply at the completion of this course include:
- Identify, read, interpret, and create appropriate graphical statistical measures for data analysis
- Identify, interpret, and calculate appropriate numerical statistical measures for data analysis
- Identify and construct appropriate sampling schemes
- Identify and apply well-known probability distributions
- Understand and apply properties of sampling distributions and the Central Limit Theorem
- Construct and interpret confidence intervals and use them for conducting statistical inference
- Perform and interpret hypothesis tests for conducting statistical inference

Course Requirements

As with most subjects, mastery of statistical techniques requires active, hands-on learning. Furthermore, the structure of the Weekend College creates a fast-paced learning environment. Therefore, the following items are required:
- attendance and participation at all class sessions,
- two in-class exams,
- graded homework assignments (likely 5 or 6),
- concept mapping assignments
- practice problems (these problems will not be collected or graded, but they will be useful in clarifying the material and in helping you master the techniques/concepts presented).

Text


Online Course Management

We will be using Sakai as an online course management system. With this site we will be able to share course announcements, handouts, problem sets, assignments, and other resources.

To log in to Sakai:
- From the college main page, scroll down the side bar on the right to Courses Online (Sakai) under Students.
- At the top of the screen, type your username and password, and click Login.
- Go to the site, click on the **Intro Stats** site tab. (You will see two or more tabs in a row across the upper part of the screen.)

Helpful Tools

- Access to a spreadsheet package, such as Excel (available on campus computers).
- A calculator that performs 2-variable statistical calculations.
Other Help

- The formation of student study groups is greatly encouraged. A contact sheet will be available for all interested students to share phone numbers, e-mail addresses, and availability.
- Tutoring help may be available by contacting the Weekend College office or Student Academic Services (Hall 105) at (330) xxx-xxxx or online from the college main page: scroll down the side bar on the right to Peer Tutoring under Students.
- The publisher of the text, W.H. Freeman, offers a free online resource site that provides many helpful tools including chapter summaries, flashcards, video clips, and practice quizzes. The web address is http://whfreeman.com/discostat

Grading

10%: Attendance and Participation

55%: Exam I & Exam II (higher score worth 30%, lower score worth 25%)
Exams will be held during regularly scheduled class sessions and are tentatively scheduled as shown in the course outline. Typically, exams consist of questions requiring short-answers and problems requiring mathematical and statistical calculations as well as interpretation of results.

15% Concept Mapping assignments
Please see the section entitled Concept Mapping for additional information.

20%: Homework assignments
Please see the section entitled Assignment Guidelines for additional information.

Concept Mapping

- We will be incorporating the use concept mapping as a learning tool. Concept maps are graphical tools for organizing and representing knowledge. Concept maps consist of concepts (words or phrases) placed in circles or boxes that are connected to each other with lines or arrows labeled with words or phrases that detail the relationship between the linked concepts. Concept maps are believed to help learners visualize abstract ideas, deepen conceptual understandings, connect and integrate new ideas with existing knowledge, and identify misconceptions and gaps in knowledge. Concept maps have been widely used in the sciences to increase meaningful learning. There has been limited application in the area of statistics. So, this semester I would like to use them in our course as a way, hopefully, to enhance your understanding of and comfort with introductory statistical concepts.

- You will be constructing a concept map after each class session as a way to organize and represent your knowledge of the concepts we have been discussing in that session. As the semester continues, you may find yourself including concepts from previous sessions in your map, or connecting your biweekly concept maps, as you relate, integrate, and build upon your knowledge. We will discuss our concept maps at the beginning of each class session.
Concept maps will be submitted at each class session and graded. Factors considered in scoring the maps include propositions, hierarchy, crosslinks, and examples.

The Assignment Guidelines below apply to both the concept mapping assignments and the homework assignments.

Assignment Guidelines

- Assignments are due on or before the date and time assigned. They may be electronically submitted by posting to the specific assignment in Sakai. Acceptable forms are Word or Excel documents or scanned copies of handwritten work. Assignments may also be faxed or submitted in class on or before the due date.

- Assignments may be accepted late under special circumstances. Please notify me by phone, e-mail, or in person before the time it is due so that other arrangements may be made. Assignments will not be accepted after solutions have been distributed or if alternate arrangements have not been agreed upon before the due date. The instructor reserves the right to reduce the assignment grade by 10% for each calendar week the assignment is late.

- Electronically submitted work should include your name in both the document name and in the text of the document and should be formatted to print appropriately. Documents not ready to print will be returned for reformatting.

- Please be as neat, organized, and concise as possible in order to expedite the return of your graded work. Clearly mark the problem numbers on your paper and arrange the problems in the appropriate order. Assignments that are not legible and/or appropriately organized will be returned ungraded. Hard copies should be stapled or fastened with clips.

- Please make your answers as concise as possible based on the question. Supporting work should be included so that I may determine partial credit and provide help. Answers without any necessary supporting work may not be given full credit even if they are correct.

- I encourage you to discuss assignments with your classmates, but you should prepare your solutions individually. Everyone must turn in his/her unique paper.
Approximate Course Outline

Please read appropriate sections before the class session.

<table>
<thead>
<tr>
<th>Topics</th>
<th>Session</th>
<th>Text Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>➢ Introduction</td>
<td>1/14 and 1/21</td>
<td>Chapters 1 – 3 (excl. 3.3), 4.1, 4.2</td>
</tr>
<tr>
<td>➢ Review of Concept Mapping</td>
<td></td>
<td></td>
</tr>
<tr>
<td>➢ Univariate and bivariate descriptive statistics</td>
<td></td>
<td></td>
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<tr>
<td>➢ Review of technology resources</td>
<td></td>
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<tr>
<td>➢ Sampling</td>
<td></td>
<td></td>
</tr>
<tr>
<td>➢ Random variables: requirements, expectation, and variance</td>
<td>2/4</td>
<td>5.1, Chapter 6 (excl. 6.2)</td>
</tr>
<tr>
<td>➢ Random variables: specific distributions</td>
<td></td>
<td></td>
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<tr>
<td>➢ Exam I</td>
<td>2/18</td>
<td>7.1, 7.2</td>
</tr>
<tr>
<td>➢ Sampling distributions</td>
<td></td>
<td></td>
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<tr>
<td>➢ Central Limit Theorem</td>
<td></td>
<td></td>
</tr>
<tr>
<td>➢ Inference: point estimates, interval estimation</td>
<td>3/3</td>
<td>8.1, 8.2, 8.5</td>
</tr>
<tr>
<td>➢ Inference: hypothesis testing</td>
<td>3/17</td>
<td>9.1 – 9.4</td>
</tr>
<tr>
<td>➢ Linear regression: least squares, inference and validation</td>
<td>3/31</td>
<td>4.3, Chapter 13</td>
</tr>
<tr>
<td>➢ Review</td>
<td></td>
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</tr>
<tr>
<td>➢ Exam II</td>
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</tbody>
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Additional Policies

Non-Discrimination Policy
The College is committed to equality of opportunity and does not discriminate in its educational and admission policies, scholarship and loan programs, and athletic and other school-administered programs on the basis of race, color, national origin, religion, gender, sexual orientation, age, or disability. The College will not tolerate harassment, prejudice, abuse, or discrimination by or of any of its students, faculty, or staff.

Communication with Parents
The College encourages students to speak directly with faculty regarding course content and performance. Students are also encouraged to speak with their parent(s), particularly if the student remains dependent on parent(s) for financial support. Faculty may choose to speak with parents, but generally, faculty will require a written FERPA waiver to be signed by the student before speaking with a student’s parent. FERPA waivers may be found at the Registrar’s Office.
Disability Support Services for Students with Special Needs
To arrange for support services, a student must submit appropriate, current, detailed documentation to the Director of Counseling, Health and Disability Services (CHDS) together with the completed online service request form. After verification and with the student’s consent, the Director of CHDS will notify the student’s faculty of the appropriate accommodation services. Faculty are not permitted to make accommodations without the authorization of the Director of CHDS. The College adheres to Section 504 of the Rehabilitation Act to provide requested services for disabled students as specified by the requirements contained in the Americans with Disabilities Act (ADA) policy guidelines.

Academic Dishonesty
There are many forms of academic dishonesty, including plagiarism, the giving or receiving of help in any form on an examination, the sale or purchase of papers and test materials, the abuse of computer privileges and regulations, the misuse or abuse of online or library resources, and any other action which debases the soundness of the educational process. Any student who violates the integrity of the academic process will be subject to punishment, including possible dismissal from the College.

The College believes that the development of intellectual honesty is at the heart of a college education. The process of education is severely compromised if we cannot depend on the academic integrity of each member of the community. Moreover, the principles of academic honesty are aligned closely with the principles of good scholarship and research, principles of critical thinking and reasoning, and the standards of professional ethics. Thus, students who fail to practice academic honesty not only risk losing the trust of the academic community, they also fail to develop the most essential skills and abilities that characterize a college graduate.

Faculty members, librarians and staff are expected to report all instances of academic dishonesty to the Associate Dean of the College, who will provide advice on an appropriate action.

Grade Appeals
Academic performance is to be judged solely by individual faculty members. Grades are not subject to alteration based on the amount of effort exerted by, or past performance of, a student. Faculty are expected to provide performance criteria (such as attendance policies, deadlines, assignment expectations, etc.) as part of course syllabi or distributed assignments, but assessment of student performance in meeting said criteria is for the individual faculty member to determine. If a student believes that criteria were ignored, or that work submitted was not included, the student should consult the “Student Academic Responsibilities and Performance” section of the College Catalog. Therein is provided the process for grade appeals. Please note that all grade appeals reside wholly with the professor alone until the official posting of grades by the Registrar.

Please note that information in this syllabus such as, but not limited to, covered topics, dates, requirements, and guidelines, is subject to change based on time constraints, class discussions, and student input. Appropriate advance notice (in class, via email, or via Sakai) will be given in the event of such changes.
APPENDIX B

KEY INFORMANT INTERVIEW PROTOCOL
Appendix B
Key Informant Interview Protocol

**Initial Interview**
1. What are your expectations for this course?
2. Describe how you feel about taking this course.
3. Before this class, had you ever used any type of concept mapping? If so, please explain.

**Interview 2**
1. Has concept mapping changed the way you study or think about the concepts you have been learning? Please explain or provide an example.
2. What do you see as the benefits of concept mapping?
3. What do you see as the difficulties of concept mapping?
4. What difficulties or challenges did you have incorporating concept maps into your learning process for this course?
5. Do you think your concept maps accurately reflect your understanding of the statistical concepts we have discussed this semester?
6. Has concept mapping helped you better understand how concepts are related? Please explain or provide an example.
7. Has concept mapping helped you better apply the concepts we have studied? Please explain or provide an example.
8. Has using concept mapping changed the way you feel about this course?

* Based on student responses, additional questions of clarification may be asked.
APPENDIX C

KEY INFORMANT JOURNAL PROMPTS
Appendix C

Key Informant Journal Prompts

First Journal Entry (to be completed after class session 2)
1. What feelings do you have about taking the statistics course?
2. What expectations do you have for this course?
3. What do you know about concept mapping?
4. How do you feel about incorporating concept maps into your learning process for this course?

Subsequent Journal Entries (to be completed biweekly after sessions 3, 4, 5, and 6)
1. How do you feel about incorporating concept maps into your learning process for this course?
2. Is concept mapping impacting how you are thinking about statistics? Please explain.
3. Is concept mapping impacting how you are feeling about statistics? Please explain.
4. Is concept mapping impacting how you study and complete problem sets? Please explain.

Final Journal Entry (to be completed after session 7)
1. Has concept mapping been helpful to you in this course? Please explain.
2. Do you have any concerns or complaints about using concept mapping in this course? Please explain.
3. Do you think you will use concept mapping in other courses or endeavors? Please explain.
4. Has concept mapping impacted how you think about statistics? Please explain or provide an example.
5. Has concept mapping impacted how you feel about statistics? Please explain or provide an example.
APPENDIX D

CONCEPT MAPPING QUESTIONNAIRE
Appendix D

Concept Mapping Questionnaire

1. Before this class, had you ever used any type of concept mapping? If so, please explain.

2. What do you see as the benefits of concept mapping?

3. What do you see as the difficulties of concept mapping?
4. Do you think your concept maps accurately reflect your understanding of the statistical concepts we have discussed this semester? Please explain.

5. Has concept mapping helped you better understand how the concepts are related? Please explain or provide an example.

6. Has concept mapping helped you better apply the concepts we have studied? Please explain or provide an example.
7. Has using concept mapping impacted or changed the way you feel about statistics? Please explain or provide an example.

8. Please share any other thoughts or comments you have on concept mapping.

Thank you for taking the time to complete this questionnaire. Your insights and comments will help me in my efforts to develop concept mapping into a beneficial learning strategy for future learners of statistics!
APPENDIX E

LETTER TO STUDENTS ABOUT CONCEPT MAPPING
Appendix E
Letter to Students About Concept Mapping

Dear Math 108 students:

This semester, I am incorporating the use of a learning tool called concept mapping into our Statistics course. Concept maps are graphical tools for organizing and representing knowledge. Concept maps consist of concepts (words or phrases) placed in circles or boxes that are connected to each other with lines or arrows labeled with words or phrases that detail the relationship between the linked concepts. Concept maps are believed to help learners visualize abstract ideas, deepen conceptual understandings, connect and integrate new ideas with existing knowledge, and identify misconceptions and gaps in knowledge. Concept maps have been widely used in the sciences to increase meaningful learning. There has been limited application in the area of statistics. So, this semester I would like to use them in our course as a way, hopefully, to enhance your understanding of and comfort with introductory statistical concepts.

With this letter, I am enclosing some training materials on the use of concept mapping as well as an addition to your First Assignment.

If you have any questions, please contact me at trehandm@xxx.xxx or (330) xxx-xxxx. I look forward to seeing all of you on the 14th!

Sincerely,

Dawn-Marie Trehan
APPENDIX F

CONCEPT MAPPING TUTORIAL
Appendix F

Concept Mapping Tutorial

What are concept maps?

Concept mapping is a learning tool that helps learners visualize and conceptualize abstract ideas, deepen conceptual understandings, connect and integrate new ideas with existing knowledge, and identify misconceptions and gaps in knowledge. Concept maps are graphical representations of concepts placed in nodes connected by links to form propositions that represent and identify the relationships between the concepts. Concept maps are organized hierarchically from the most general to more detailed and focused ideas. They are thought to reflect, and deepen, a person’s understanding of a subject because it is necessary to not only list concepts but to link them by their relationships and show connectedness of ideas.

What are concepts, links, and propositions?

A concept is defined as “a regularity in events or objects designated by some label” (Novak & Gowin, 1984, p. 4). That is, the mental image that emerges when you hear a word is considered a concept. Examples include: chair, dog, weather, mathematics, studying, thinking, eating.

A link is a word or phrase that connects two or more concepts to form a proposition about the concepts. Examples include: is, is not, by, with, requires, determines, leads to, can be, made of, for example.

A proposition represents a meaningful relationship between concepts. Examples include: cats are animals, dogs can be long-haired, water made of molecules, mathematics has many branches, studying requires concentration.
Other characteristics and components of concept maps

Concept maps are represented graphically, or visually, with the concepts placed in circles or boxes and the linking words or phrases placed on lines that connect the concepts.

Concept maps are organized hierarchically with the most inclusive and general concepts at the top and the more specific and less general concepts below. Concept maps may include cross-links: “links between concepts in different segments or domains of the concept map” (Novak & Cañas, 2008, p. 2). Cross-links show how a concept in one area of the map is related to a concept in another area of the map. These relationships often symbolize the creation of new knowledge or integration of a new idea into existing knowledge by the learner.

Concept maps may include specific examples of a given concept. These items are generally not encased in a circle or box in order to differentiate them as specific examples rather than concepts.
Example of a concept map of concept maps (reprinted from Novak & Cañas, 2008)

What is the origin of concept mapping?

Concept maps were formally developed by Joseph Novak in the early 1970s. Novak was conducting a 12 year longitudinal study of science learning aimed at examining changes over time in students’ understanding of science concepts. Concept mapping began as a result of looking for ways to organize a multitude of information from many interviews and transcripts of learning of science concepts by first and second graders. A key objective of that organization of material was to be able to clearly examine and illustrate students’ concept meanings and deep understandings. Over time, it was determined that the actual construction of concept maps offered an effective way for individuals to learn how to organize and represent their knowledge and even to help them create knowledge.
What are concept maps used for?
Concept maps are used in varied settings, such as business, healthcare, and education, for program development and evaluation, planning, and assessment. In education, concept maps are used for curriculum development, instructional design, and program evaluation. Concept maps are used in the classroom for lesson planning, instructional aids, learning tools, and assessment and evaluation of content knowledge.

What are the benefits of concept mapping as a learning tool?
Concept maps used as a learning tool may:
- help to organize knowledge
- promote explicit construction and description of new concepts
- foster the development of relationships between concepts
- help to integrate new concepts with existing knowledge
- identify misconceptions or gaps in knowledge
- encourage reflection and self-evaluation
- provide a forum for collaboration and discussion regarding the concepts
- further the development of deep meaning and understanding of the material

Tips for constructing concept maps
Novak suggests expressing your topic as a focus question, e.g., How do you play football?; What is statistics?; How is the weather forecasted?; How can we help the environment?; What is a cloud?
Once you have chosen your topic, brainstorm concepts related to your topic. You may want to start with 8-10 concepts. Be sure your concepts are general ideas (e.g., college, dog, basketball player) and not particular entities (e.g., our college, my dog Rover, Michael Jordan).
Order your concepts beginning with the most general and moving to the more specific. Place your concepts in circles or boxes.

Connect the concepts with explicit linking words to form propositions. Place the linking words above lines drawn between the concepts. Use arrows if showing order or direction is important.

Search for crosslinks to show relationships between concepts in different sections of the map.

Helpful hints:

If constructing maps manually, you may want to write the concepts on individual post-its so that they may be easily rearranged.

Plan on revising, repositioning, and refining your map several times!

**How will we be using concept maps?**

You will be constructing a concept map after each class session as a way to organize and represent your knowledge of the concepts we have been discussing in that session. As the semester continues, you may find yourself including concepts from previous sessions in your map, or connecting your biweekly concept maps, as you relate, integrate, and build upon your knowledge. We will discuss our concept maps at the beginning of each class session.

Hopefully, you will experience some of the benefits listed above through your construction and use of concept maps in this course. Novak reported that “students and teachers constructing concept maps often remark that they recognize new relationships and hence new meanings (or at least meanings they did not consciously hold before making the map)” (Novak & Gowin, 1984, p. 17).

A common challenge often articulated by students in statistics courses is relating the various concepts, techniques, and formulas in order to develop a sense of “the big picture.” In other words, how can the techniques and concepts learned be integrated and applied in order to solve a real-world problem for which you have
data? Concept mapping may help you develop this “big picture” by encouraging you to explicitly identify and relate these ideas.

**Online Resources**

To learn more about concept mapping:

- [http://cmap.ihmc.us/](http://cmap.ihmc.us/)
- [http://www.studygs.net/mapping/](http://www.studygs.net/mapping/)

For straightforward explanations of how to construct a concept map:

- [http://www.udel.edu/chem/white/teaching/ConceptMap.html](http://www.udel.edu/chem/white/teaching/ConceptMap.html)

For concept mapping software:

- [http://cmap.ihmc.us/download/](http://cmap.ihmc.us/download/)
Examples:

Simple Concept Map for Trees (reproduced from Birbili, 2006, Figure 2)

Concept Map for Water containing cross-links and examples (Novak & Gowin, 1984, p. 16)
First Assignment

For the first class session, please complete two concept maps, as described below. We will discuss these maps in class on January 14, 2012, and they will be collected and graded for completion.

1. To practice your emerging knowledge of concept mapping, I have provided below a list of concepts, what Novak calls the “parking lot,” regarding the game of basketball. Use your understanding of basketball, the concepts provided, and your own linking words and phrases to develop a concept map of The Game of Basketball. You may also add examples if you like. You may create your map with pencil and paper; word-processing, presentation, or other software; or automated concept map tools (see resources above).

2. Now create your own concept map about something of personal interest. You may choose to map a hobby, your work responsibilities, another course, one of the focus questions above, etc. You may create your map with pencil and paper; word-processing, presentation, or other software; or online automated concept map tools (see resources above). Be sure to use at least 8 concepts in your map.
Questions?

Please contact me at trehandm@xxx.xxx or (330) xxx-xxxx.

References


APPENDIX G

EXAMPLES OF STUDENT CONCEPT MAPS
Appendix G

Examples of Student Concept Maps

Carol’s CM3 Concept Map
Geoffrey’s CM4 Concept Map

Scatter Plot Concept

- Shows the relationship between paired data and
- Between two quantitative variables on the same subject
- Other strength of the relationship and
- How closely the points follow a clear pattern

A linear relationship of the points
- Formed in a straight line
  - Can form a straight line

Show the direction in the linear relationship and
- Positive or negative
Cole’s CM5 Concept Map
Jessica’s CM7 (Final) Concept Map

- Target Number
  - position of each value
  - quartiles
    - IQR
- Mean
- Deviation
- Variance
- Relationship to deviation
- Z-score
- Central Limit Theorem
  - Sample data
  - P-Value
  - Hypothesis testing
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