Fostering Change in College Students' Statistical Reasoning and Motivation through Statistical Investigation

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Abstract

The goal of this study was to examine the reciprocal relationship between statistical investigation and motivation of college students in a Mathematical Reasoning course (Math 1). Unlike previous studies in which students' projects or statistical investigations have been examined as the final product that shows evidence of statistical literacy, reasoning and thinking, the focus of this dissertation was to explore students' motivation as they completed the process of statistical investigation. The purpose of this study was to give voice to students' experiences with the statistical investigation, and to showcase the development of their projects.

The statistical investigation had the following phases: (1) formulating a question; (2) collecting data; (3) analyzing the data and interpreting the results; and (4) final project and reflection on the process. These phases were developed based on the Guidelines for Assessment and Instruction in Statistics Education (GAISE) framework. I analyzed the written assignments in all four phases from a group of 60 students. An artifact-driven interview was conducted on a subset of seven students, who were purposely selected to represent students with projects of varying quality. In order to understand whether and how students' motivations were manifested within the context of a statistical

investigation activity, I used the Expectancy-Value Theory (Wigfield & Eccles, 2000) to analyze students' statements. The central research question that guided this study was: When students are given the opportunity to pick their own topics, write their own survey questionnaire, collect their own data, and analyze the results, what can we learn about changes in students' statistical reasoning and motivation?

There were three major findings that emerged through this study. First, although the students were required to collect both categorical and continuous data in their survey, some students only collected and used categorical variables. Second, the quality of the analysis was significantly associated with the nature of the data (i.e., categorical and continuous data). Most students who focused on collecting and analyzing categorical variables were able to adequately analyze their data; while the majority of those who focused on collecting and analyzing both types of variables were not successful in analyzing their data. Third, the statistical investigation task provided a context for understanding students' motivation and learning. Analyzing these projects in terms of motivation made clear the trade-offs between the cost of doing the project and the value that students assigned to completing it. Findings have implications for helping instructors find the right balance between promoting students' motivation by encouraging them to choose topics of interest and the difficulties of conducting statistical investigations, in particular designing appropriate survey questions and figuring out how to analyze the subsequent data. Researchers and instructors need to pay attention to the ways in which student generated data can limit or support the analysis.

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Chapter 1: Introduction

1.1 Research Problem

Statistics education research has placed increasing emphasis on the study and assessment of statistical literacy, reasoning and thinking (Ben-Zvi & Garfield, 2004; Garfield & Ben-Zvi, 2008). Statistical reasoning and literacy are important resources for functioning effectively in environments that value information and numeracy because these are central in making informed decisions based on numerical data (Gal, 2002; Utts, 2003). The National Council of Teachers of Mathematics (NCTM) recognizes the significance of including statistics in K-12 school curriculum, along with number sense, algebra, geometry and measurement (NCTM, 1989, 1991). Similarly, the American Statistical Association (ASA) endorsed the Guidelines for Assessment and Instruction in Statistics Education (GAISE) to improve statistical reasoning and literacy of students in all educational levels (Franklin & Garfield, 2006; Franklin et al., 2007). Both organizations, NCTM and ASA, follow a constructivist philosophy of advocating a problem centered approach to teaching math and statistics, such as having students participate in small group activities, providing students with problem solving activities grounded in real world contexts, and asking them to perform statistical investigations. In doing statistical investigations students are encouraged to pose questions, collect and analyze data, and interpret the results with respect to the context, therefore applying the concepts of statistics rather than just learning algorithms and procedures. This dissertation study examined students' work in conducting statistical investigations designed to promote statistical reasoning and literacy. I was specifically interested in the relationship between motivation and statistics. Before I describe the research problem, I

contextualize it by showing a brief overview of statistics education research, specifically in the area of statistical literacy, reasoning and thinking.

1.1.1 Contextualization of the Problem

Wallman (1993) defined statistical literacy as the "ability to understand and critically evaluate statistical results that permeate our daily lives – coupled with the ability to appreciate the contributions that statistical thinking can make in public and private, professional and personal decisions" (p. 1). This definition highlights the need to explore students' appreciation of statistics, emphasizing that statistics educators and researchers must understand the cognitive processes that enable statistical literacy and learning to take place. Conversely, we should also explore how motivation and dispositional factors influence cognition.

With regard to learning statistics, Garfield and Gal (1999) defined statistical reasoning as "the way people reason with statistical ideas and make sense of statistical information" (p. 207). Statistical reasoning activities include interpreting descriptive statistics, or making sense of visual representations of data, as well as making connections between statistical concepts, such as the mean and standard deviation (Ben-Zvi & Garfield, 2004). These activities are still related to statistical literacy. For example, in reading newspapers laden with statistical information, statistical literacy can be manifested by comprehending the statistical terminology and by having a critical stance, while statistical reasoning can be activated in comparing statistical measures (e.g., center and spread) and in interpreting the data.

Moore (1998) advocates the idea of teaching statistical reasoning in the context of liberal arts and philosophy, especially for freshmen college students, because liberal arts

courses promote "modes of reasoning needed in civilized society… and it emphasizes that these ways of thinking must be learned" (p. 1256). Rather than focusing on computations by using formulas and calculating numerical answers, statistical reasoning involves context, interpretation, and forming valid conclusions based on the data. Thus, the dependence on data and context are the reasons why most statisticians advocate the use of statistical investigation in teaching introductory courses to make statistical reasoning and thinking visible (Ben-Zvi & Garfield, 2004; Chance, 2002; Wild & Pfannkuch, 1999).

Ben-Zvi and Garfield (2004) noted that statistical thinking involves "understanding of why and how statistical investigations are conducted… when and how to use appropriate methods of data analysis such as numerical summaries and visual displays of data" (p. 7). This means that when students engage in statistical investigations, statistical thinking and reasoning are needed in analyzing the data with respect to the context, which is manifested in how students interpret their results.

1.1.2 Problem

In theory, statistical investigation holds great promise in fostering students' statistical literacy, reasoning and thinking. However, not all students experience a successful statistical investigation, and there have been many challenges in using this as an alternative assessment (Chance, 2002; Holmes,1997; Wild & Pfannkuch, 1999). It is possible that students with unsuccessful statistical investigations are also struggling with their developing statistical reasoning and literacy. Additionally, there have been few efforts to study the role of motivation in students' engagement (or disengagement) in the

process of statistical investigation. This indicates the need to explore the relationship between motivation and statistical investigations.

Although motivation has been widely recognized for its importance in education (CDE, 1992; NCTM, 1989, 1991; Stipek, 1998; Stipek, et al., 1998), its relationship with statistical investigation remains unclear. Motivation is a multidimensional construct that is related to underlying psychological processes, including self-efficacy (Bandura, 1986; Pajares, 2005; Schunk, 1990), goals (Dweck, 1986; Elliot & McGregor, 2001; Pintrich, 2000; Stipek, 1998), and values (Wigfield and Eccles, 2002). Attending to motivation can provide reasons why some students perform differently from others, why some students enjoy statistical investigations, why some learn more than others from the work of doing investigations and why some experiences lead students to want to take more statistics courses. It is therefore important to explore and give voice to students' experiences with statistical investigation, particularly their motivation, so that statistics educators can design projects that will promote an appreciation of statistics as students apply the concepts they learn about in class to their own investigations.

1.2 Purpose of the Study

Unlike previous studies (Forster & MacGillivray, 2010; Holmes, 1997; Lajoie, 1997; Loi, 2002; Pimenta, 2006), in which students' statistical investigations have been examined as the ***final product*** that shows evidence of statistical literacy, reasoning and thinking, this dissertation study attempted to explore students' motivation as they completed the ***process*** of statistical investigation. The purpose of this study was to give voice to students' experiences with the statistical investigation, and to show the development of their project. I examined 60 students' homework assignments for the

statistical investigation, which had the following phases: (1) formulating a question; (2) collecting data; (3) analyzing the data and interpreting the results; and (4) final project and reflection on the process. I also interviewed seven students to learn more about their motivation and experience with their statistical investigation. Hence, I aimed to see whether and how students' motivations were manifested within the context of a statistical investigation activity.

Another purpose of this study was to examine the motivations and statistical learning of students in a mathematical reasoning course (Math 1). This course is typically taken by college students whose majors do not include a specific mathematics requirement. A large majority of college students take this course, but they are usually underrepresented in statistics education research. The lack of research in this area might be due to the following reasons: first, Math 1 is not a typical first course in statistics; and second, inferential statistics are excluded in this class. Unlike most studies in statistics education that examined college students in an elementary statistics course, this study explored the statistical learning of students, particularly the descriptive statistics that they show in their statistical investigations. The students were given the opportunity to formulate their own research questions based on their interest, develop their own survey questionnaire and collect data, analyze and interpret the results, and showcase their work in a final report. Through these tasks, I aim to uncover students' statistical learning in Math 1.

1.3 Research Questions

This dissertation study examined the relationship between students' motivation and their statistical investigation, with the aim of promoting statistical literacy, reasoning and thinking. With this in mind, the central research question for this study was: *When students are given the opportunity to pick their own topics, write their own survey questionnaire, collect their own data, and analyze the results, what can we learn about the changes in students' statistical reasoning and motivation after engaging in the process of a statistical investigation*?

In order to unpack the central research question and better understand the relationship between statistical investigation and motivation, I examined following:

1. What do students' statistical investigations look like based on their written work during the four phases of the investigation?
2. What strategies do students use in analyzing their data? Which categorical and/or continuous variables do students use in the analysis and how do they analyze the data?
3. How do students' levels of motivation, in particular, their subjective task value, result in the completion of the statistical investigation or academic effort?
4. What statistical learning do the students show or articulate after conducting the statistical investigation?

1.4 Overview of the Dissertation Chapters

Brief descriptions of the chapters are provided in this section to orient the reader to subsequent chapters. Chapter 2 is the literature review which explores the relevant literature in both statistics education with a focus on statistical investigations and motivation, specifically in the area of Expectancy-Value theory (Wigfield & Eccles, 2000). Chapter 3 provides detailed descriptions of the methodology, which includes both qualitative (i.e., content analysis, case study, and artifact-driven interview) and quantitative methods (i.e., descriptive statistics and chi square test).

Chapters 4, 5 and 6 present the major findings from the dissertation study. Chapter 4 shows a micro view of a successful statistical investigation from one of the students in this course, named Hannah (pseudonym), along with a description of her motivation. Chapter 5 shows a macro view of the statistical investigations from the 60 students who completed the project, plus an analysis of the learning gains as measured by pre and post tests. I found that although the students were required to collect both categorical and continuous data in their survey, some students only collected and used categorical variables. Quantitative analyses revealed that there is a significant relationship between the quality of the analysis and the nature of the data (i.e., categorical and continuous data). Chapter 6 is a cross case analysis of six focal students who represent varying degrees of quality in their statistical investigations, with a range of experiences and motivation. I found that the statistical investigation task provided a context for better understanding students' motivation and learning. The last chapter summarizes the major findings and discusses the results, which also includes the implications, recommendations, limitations and future work.

Chapter 2: Literature Review and Theoretical Frameworks

The body of research on statistics education is growing in the United States and abroad. There are substantive research literatures focused on how students learn probability and statistics at the elementary, high school, and college levels (Baker & Beisel, 2001; Cai, Lo, & Watanabe, 2002; Konold & Pollatsek, 2002; Mokros & Russell, 1995; Shaughnessy, 2007; Strauss & Bichler,1988). Curriculum reform documents in mathematics have also made important contributions in recognizing the need for K-12 teachers to pay attention to, support, and assess students' attitudes, dispositions, and motivations in mathematics (NCTM, 1989, 1991). Although ample research attests to the importance of statistical literacy, reasoning, and thinking, there have been few efforts to investigate the role of motivation in students' engagement in the process of statistical investigation to develop their statistical reasoning and literacy. I argue that students' motivation toward math and statistics can be enhanced by engaging in statistical investigation. By having positive motivation in an academic context, students can deepen their understanding of statistical reasoning and literacy. Thus, the focus of this literature review will be on the relationship between motivation and statistical investigation, situated in the growing field of statistics education.

This dissertation is grounded in the literature from two major areas of research: (1) statistics education and (2) motivation. I begin by reviewing the literature on statistical investigation, which includes the various theoretical perspectives, practical applications, and the evaluative research on the effectiveness of projects. Next, I discuss the theoretical frameworks that I used in guiding this study, particularly the Expectancy-Value Theory of motivation by Wigfield and Eccles (2000). I review specific studies in

which the researchers described the relationship between students' motivation and statistical investigations. Finally, I present a conceptual framework that emerged from this literature review.

2.1 Literature Review on Statistical Investigation

According to DeVeaux and Velleman (2008), math is like music and statistics is like literature. That is, mathematics is based on its "axiomatic structure and logical development" (p. 54), which a math prodigy could figure out for him/herself without much experience in the world. However, child prodigies in statistics do not exist because it takes maturity and experience to develop judgment and reasoning about the real world. Thus, statistical investigation, which involves reasoning, is very similar to understanding and appreciating literature, because it requires a degree of maturity and reasoning with the contextual nature of the data. This reasoning component is probably why DeVeaux and Velleman believe that we do not have six-year-old novelists. Furthermore, delMas (2004) noted that mathematics is essentially metaphorical in nature because of the abstract nature of math and that it is an abstract artifact of human intellect and culture. Scheaffer (2006) pointed out that mathematical reasoning involves logical reasoning, patterns, optimizations and showing proof.

On the other hand, statistical investigation depends on data and its context. Moore (1998) notes that

> Statistical thinking is a general, fundamental, and independent mode of reasoning about data, variation, and chance. Elective use of statistical reasoning requires considering the zeroth problem and interpretation of formal results in the context of a specific setting. Statistical thinking is an artifact of civilization, not part of our natural neural equipment. It is learned in part from well-chosen examples rather than entirely from

> general theorems. All this fits the description of statistics as a liberal art. (p. 1257)

Similarly, Rossman, Chance and Medina (2006) emphasized the crucial role of context in statistics, while mathematical theorems can still be understood independent of context. They assert that "*statistics is a mathematical science*" (p. 323), which succinctly captures the essence of this discipline. They then explained why they chose the singular form "is" in their definition to emphasize that statistics is a field of study, and that the word "mathematical" is used as an adjective where math is used in statistics. Finally, they used the word "science" to describe the interpretive nature of statistics and its dependence on data and context. Due to the contextual nature of statistics, they contend that some mathematically proficient students become frustrated with statistics because it goes beyond using formulas, rather statistics requires reasoning.

In summary, statistics and mathematics are separate disciplines because of the applied nature of statistics in contrast to the abstract nature of math. Furthermore, when engaged in statistical reasoning students must account for the data in context, while students can engage in mathematical reasoning without referring to a context. As Bessant & MacPherson (2002) noted

> knowing how to carry out a series of computational steps does not ensure an understanding of statistical concepts, formulas, or their application to real-world problems. This issue is particularly relevant to statistics learning insofar as increased pedagogic emphasis on concepts may facilitate students' abilities to apply knowledge and skills to novel situations. By comparison, instruction that focuses primarily on computational or algorithmic procedures is likely to enhance, especially in the minds of liberal arts students, the perception that statistics is very much like mathematics (p. 26).

Viewed in this light, I contend that statistical reasoning can be fostered and strengthened in a reform or non-traditional math class, especially when taught in the context of liberal arts and with the goal of developing students' statistical literacy. I argue that students can develop their statistical literacy and deepen their statistical reasoning by conducting statistical investigation.

2.1.1 Theoretical Perspectives

One of the models of statistical investigation was conceptualized by Friel and Joyner (1997). They noted that it is important for students to pay attention to the process of statistical investigation when handling data that they have collected or that they have been provided. They theorized that the process of statistical investigation has four main components: posing one or more questions, collecting data, analyzing the distribution(s), and interpreting the results. This framework also emphasizes that the process of statistical investigation is dynamic, that it is iterative, and that the components are interconnected. For example, students can go through an iterative process of refining the questions that were initially posed as they engage with data collection and analysis.

Similarly, the authors of the GAISE report suggested that students should experience the four process components of a statistical investigation: formulating a question, collecting data, analyzing the data, and interpreting the results (Franklin & Garfield, 2006; Franklin et al., 2007). These four components provide students a scaffolding structure to conduct research and empirical investigations to develop statistical reasoning and literacy, similar to the model proposed by Friel and Joyner (1997). However, the GAISE framework has a more linear and less dynamic view of the process of statistical investigation as compared with Friel and Joyner's model. The

authors of both frameworks advocate that students develop their own set of questions and collect data, rather than focusing on algorithmic computations or working on textbook exercises. Lajoie (1997) developed the Authentic Statistics Project (ASP), which included conducting a statistical investigation, which happens when students develop their own research question, collect their data, graph, analyze, and interpret such data. This exploration is again similar to the previous models, particularly the GAISE framework, because of its linear representation of the statistical investigation.

Chance (2002) suggested that teachers who use statistical investigations need to emphasize the iterative cycle, and it is important for students to understand this process in its entirety. Perhaps a more detailed model of statistical investigation might be helpful in capturing the complexities of the process, as well as in situating the statistical investigation in the larger field of statistical thinking. A more complex model developed by Wild and Pfannkuch (1999) includes statistical investigation as one of the dimensions in statistical thinking. The four dimensions of statistical thinking are as follows: (1) investigative cycle; (2) types of thinking; (3) interrogative cycle; and (4) dispositions. Wild and Pfannkuch claimed that these dimensions can happen simultaneously, and not as a series of steps. Further, this model assumes that statistical investigation is one of the dimensions of statistical thinking. In the first dimension, the student or the thinker might be planning and conducting the statistical investigation, and then the student might start to think about the variability in the data in the second dimension, followed by two more cycles of critique and skepticism about the results of the data. In this model, statistical investigation happens in the first dimension with the following components, also known as the PPDAC model: (1) problem; (2) plan; (3) data; (4) analysis; and (5) conclusion.

Wild and Pfannkuch emphasized the cyclic process that goes on between components, similar to the model proposed by Friel and Joyner (1997). Shaughnessy (2007) noted that this model is different from George Polya's four-step model of mathematical problem solving (understand, plan, execute, review) in that "statistical problems are ill posed at first, as they arise out of messy contexts" (p. 963). Recall that statistics depends on data and contexts, which adds a layer of complexity to the process of statistical investigation, and the iterative nature of the process makes statistics more challenging than solving mathematical problems. Both models, the process of statistical investigation by Friel and Joyner (1997) and the investigative cycle developed by Wild and Pfannkuch (1999), show the iterative and dynamic interactions between components.

Wild and Pfannkuch's (1999) model acknowledged some motivational factors in the third and fourth dimensions: *interrogative cycle* and *dispositions*, respectively. Being able to criticize and judge are some of the important components of the interrogative cycle, which also complements dispositional factors such as skepticism, curiosity, and awareness. These are similar to the dispositions and motivational factors in statistical literacy, which consist of a questioning attitude (Wallman, 1993; Watson, 1997), beliefs, attitudes, and having a critical stance (Gal, 2002). In addition, Shaughnessy (2007) noted that the interrogative cycle also requires explicit metacognitive activity and reflection, while the disposition dimension takes place not only in statistical investigation but in mathematical problem-solving activities as well.

However, most of the above theories or frameworks were not designed to include motivational constructs, with the exception of Wild and Pfannkuch's (1999) model. Gal, Ginsburg, and Schau (1997) noted that as more alternative assessment strategies and

reform teaching methods are used in the classroom, more research is needed to understand students' attitude, beliefs, and motivation, because these nontraditional learning contexts are more likely to cause affective responses than the traditional curricula that most students are already familiar with. This current gap in the literature between statistical investigation and motivation is problematic, given that motivation plays an important role in students' learning.

2.1.2 Statistical Investigation in Practice

In general, statistical investigation can be considered as an alternative form of assessment in making students' learning and reasoning visible, instead of using traditional paper and pencil exams. Garfield and Ben-Zvi (2008) noted the various ways that statistical investigations or projects can be used in the classroom for "both assessing many aspects of student learning as well as helping them experience different stages in posing and solving a statistical problem" (p. 80). Researchers have typically investigated or explored various ideas on how to implement and evaluate students' statistical investigations. The bulk of the research that has addressed the enactment or practice of statistical investigations can be organized into the process or phases based on the GAISE framework (formulating a question, data collection, analysis and interpretation).

Process of Statistical Investigation: Formulating a Question. Whitin's (2006) study of how students pose questions merits the attention of those using statistical investigation in developing students' critical stance. He studied the critical orientations of students in grade K-5 classrooms, and recommended a framework to enhance the critical perspectives of students. He found that after conducting the process of statistical investigation, a review of the whole process helped the students realize that the way a

question is posed or worded can influence the kind of responses or data received. Whitin suggested the following strategies that teachers might use to help students develop a critical attitude toward statistics: (1) questioning the question, (2) examining what the data do not say, (3) analyzing the categories of the data, and (4) identifying the background knowledge and experience of the sample population. Thus, formulating questions for statistical investigation can help students in developing their statistical thinking and literacy.

The type and quality of students' questions also depend on the students' interest, which might be different from those that are found in textbooks (Albert, 2000). And because students' backgrounds and interests vary by country of origin and the context (e.g., courses those students are taking), these variables should be examined as well. Table 2.1 shows some examples of questions or topics from students who collected their own data as part of a course requirement, competition, or program. This is not a definitive list of topics or research questions, but rather shows the variety of topics that students chose for their statistical investigations. Notice that there are some patterns that one can see from the list of questions and the context in which the statistical investigations were enacted. For example, college students in a nonparametric statistics course have very different set of questions or topics as compared to students from non-science majors, community college students and those from an elementary statistics course. There is also variation in the questions of the students from other countries depending on the background of the students and their level of interest. For example, the students from Brazil in a teacher preparation program will naturally gravitate towards topics related to

students and teachers, while seventh grade students from Portugal will have a different set of questions or topics.

Table 2.1: Examples of Students' Questions or Topics by Country of Origin

Country	Context	Questions or Topics
U.S.A.	College students in an elementary statistics course	Do you regularly attend university sporting events? Do you own a car? Do you drink regularly on weekends? Do you enjoy living on campus? Do you have a TV in your room? (Albert, 2000)
	Community college students	Comparing the markets for two competing makes of vehicles in the same place or in two places far enough apart that they can be considered separate markets Compare the markets for cars sold online with cars sold in newspapers (Brown, 2006)
	College students in a nonparametric statistics course	Lengths of needles from white pine trees "Weights of 20 random guys" (quote from a student's paper) Ages of skydivers from one drop zone in the U.S. Playing times of 32 classical music compact discs (Coakley, 1996)
	College students of non-science majors	Favorite color jelly beans Candidate preferences Weight room facilities (satisfaction level) Changes in physical condition, eating habits and exercise habits (Fillebrown, 1994)
Brazil	Students in a teaching program	Teacher development for teaching handicapped students Benefits of education of handicapped students Types of handicaps Prejudice Teachers' attitudes towards the inclusion of handicapped students (Biajone, 2006)
Ireland	Secondary students in a young scientist's exhibition	A simulation study (using Markov Chain Monte Carlo methods) of the game of Monopoly Survey of depression in adolescence (n = 590 students) Breast feeding—attitudes and intelligence aspects The influence of birds on the distribution of Xanthoria-Parietina (Boland, 1998)
Australia & New Zealand	College students in an elementary statistics course	Transportation Experiments Student environment (incl. housing) Clothes, food, drink Media Sport and general interest (Forster & MacGillivray, 2010)
Portugal	7th-grade students	Characteristics of the school students Alcohol consumption, smoking habits and drugs (Santos & Cesar, 2006)

Some instructors prefer to bypass students' collecting their own data and have students examine secondary data in order to minimize sampling bias and errors. Shen, Li, and Lam (1990) explained that during the first 3 years of Hong Kong's Statistical Project Competition, the students were required to use government data because of its reliability and that judges could easily verify the accuracy of the results. They noted that "if students were in the streets collecting data, their safety may be a concern to parents, teachers, and school principals" (p. 215). They later realized the disadvantages of using secondary data, particularly in having limited topics, and not giving the students the opportunity to collect and compile their own data. This restriction was lifted, but only for the senior students. Nonetheless, the advantages of using secondary data are still widely acknowledged by the research community, as can be seen from the sample of questions or topics in the table below. Notice that the questions or topics are again closely related to the context.

Table 2.2: Examples of Students' Questions or Topics Based on Secondary Data

Country	Context	Questions or Topics
Germany	Future secondary teachers	Overweight and going in for sports Computer and internet use Homework (Biehler, 2007)
United Kingdom	College students	Did patients receiving the new drug lose significantly more weight than those who received the placebo? Can we predict change in triglyceride level from change in weight? How does adding sugar to low GI breakfast affect children's hunger later in the day? Do gender, age, or marital status affect the risk of taking an overdose? Are larger clinics more successful than smaller ones at IVF treatment? (Bigood, 2006)
Argentina	College students majoring in statistics and in an internship	Forecasting future sales of a steel company Study of the services in the Public Health sector Study of the rivers' height in the Andes ranges in the Esquel zone in the Chubut province (Blacona, 2006)
Denmark	College students majoring in mathematics	Statistical methods to determine safe doses of carcinogenic substances Analysis of multispectral satellite pictures Modeling calcium transportation through cell membranes A model for periodic selection in *E. coli* bacteria (Niss, 2001)

Dierker, Kaparakis, Rose, Selya, and Beveridge (in press) encouraged the students to develop their own research questions based on the available variables in large datasets and/or secondary data. At Wesleyan University's Passion Driven Statistics Course, the students use the following datasets for their projects: The General Social Survey (GSS), Forest Caterpillar Ecology, and the National Longitudinal Study of Adolescent Health (Add Health). These are all available online (http://www.wesleyan.edu/qac/curriculum/). Other instructors assigned students to a particular research question, so that each group would have a different project (Nordmoe, 2007).

Data Collection. Some statistics educators require their students to collect their own data (Albert, 2000; Spence, Sinn, & Briggs, 2009), while others discourage it because there are large datasets that are available that can lead to more sophisticated projects (Dierker & Beveridge, n.d.). Still, others allow both options to their students, to either collect their own data or use secondary data, depending on the situation (Sisto, 2009; Forster & MacGillivray, 2010; Yesilcay, 2000). Forster and MacGillivray (2010) found that 26% of 120 projects used data that were researched and collected by engineering students, while only 6% used data from workplace sources, possibly from internships. They also noted the types of investigations, and they found that 31% were observational, 20% were designed experiments, and 16% surveys, but it was unclear if the students used primary or secondary data.

Other instructors have a more structured approach to collecting data from online databases such as census data (Sweet, Morgan & Johnson, 2008), or collecting survey data amongst the students themselves, such as the *Data Gathering Survey* (Neumann, Neumann & Hood, 2010). Gnanadesikan, Scheaffer, Watkins, & Witmer (1997)

emphasized the "difficulty and importance of collecting data that fairly represent a population" (p. 6). Pimenta (2006) reported that 15% of students incorrectly characterized the sample, and that 6% of students collected data inappropriately, while only 25% collected data by developing their own survey questionnaire. Very little research mentions the representativeness of the population and describes how the data were collected, as well as the appropriateness of the data collection methods.

Loi (2002) examined the experiences of students who conducted a statistical project during their final year at a business school in Singapore. One of the findings from that study is that some of the students designed their own questionnaires and conducted surveys to obtain their raw data. Of these students, 57.8% conducted interviews, 43.2% sent surveys by mail, and 34.4% via online methods, which shows that there are some overlaps in the methods of collecting data because the percentages add to more than 100%. Loi noted that although the students were able to collect their own data, the lack of a theoretical framework that grounded the design of the questionnaires was a major weakness in most of the projects, which also included a lot of items and multilevel response scales. The validity of the survey questionnaire and its theoretical basis are important elements in survey research that are often excluded in an elementary statistics course, more so in courses that use large datasets or secondary data since there is no need to construct or develop a survey questionnaire.

Data Analysis and Interpretation of Results. Loi (2002) found that majority of the students, 89.2%, used descriptive statistics in summarizing the data, which included the mean, standard deviation, and frequency tables. In the exploratory data analysis phases, looking at graphs or visual displays of data can be helpful, but Loi found that only about

half of the students used some form of graphical display of the data. A majority of them used bar charts (54.1%), pie charts (45.9%), and line graphs (34.4%). Loi also noted that only 6.2% used box-plots, while only 1.2% used stem-and-leaf plots, which are commonly used by statisticians. However, Loi did not report on the quality or the accuracy of the students' interpretations of the visual displays of data for either tables or graphs. It would be helpful to evaluate students' interpretations.

Pimenta (2006) reported that 62% of the students were able to correctly interpret a table, while the remaining 38% had some errors in the interpretation. As for the visual displays of data, 62% of them were able to produce the graphs correctly, and only 8% of the students had errors in the interpretation of the graphs. Seventy-four percent of the students were able to summarize key aspects of the data through descriptive statistics, and the majority of them were able to show correct interpretation of the measures of central tendency (71%) and dispersion (56%). The results here show that although some students were able to produce the graphs and calculate descriptive statistics, some of them showed inaccurate interpretations.

Researchers in statistics education have noted the insufficiency of using statistical investigations as the only tool in fostering students' statistical thinking and statistical problem solving strategies (Chance, 2002; Lane-Getaz, 2006; Wild & Pfannkuch, 1999). Holmes (1997) found errors in students' data analysis, for example, wrong placement of fitted regression line, arithmetic errors in calculating the mean, and errors in diagrams. Lane-Getaz (2006) examined the interpretations and conclusions of her students' final projects, and found evidence of their lack of statistical thinking. Similarly, Lajoie (1999) also found misinterpretations and confusions in the oral presentations of the statistical

projects of students in eighth grade. Zeleke, Lee, and Daniels (2006) also identified examples of students' misuse of terminology, misinterpretation of results, and inappropriate application of concepts (e.g., right chart with wrong data, wrong chart with right data, and inappropriate use of summary statistics).

Thus, assessments within the components of statistical investigation must be integrated with instruction, along with feedback to the students (Starkings, 1997). Jordan (2007) recommended that instructors should "provide appropriate scaffolding for students while they learn the process of data analysis. This scaffolding should not be too directed and specific (e.g., "Create a scatterplot and interpret"), yet neither should it be directionless (e.g., "Analyze these data.") (p. 3)." The use of feedback and scaffolding are important elements of instruction that can help students in having a successful statistical investigation.

Variations in the Final Project. Many instructors require a written report, but there are other ways to demonstrate the statistical investigation, such as a poster, portfolio, presentations, or a combination of all products. Oral presentations were also suggested as a way for students to learn how to effectively communicate statistical information (Albert, 2000; Jolliffe, 1997; Love, 2000; Smith, 1998). Mackisack (1994) used ungraded oral presentations as a way of giving feedback before the students submit the final reports. She said:

> Each group has to do a presentation as a precondition for their written report to be accepted, and they receive feedback particularly about the description of procedures and analysis of their results which they can incorporate in the written version if they wish. Marks are allocated for the written report. (p. 4)

There are also variations in the structure of the written report. Some have required their students to submit a project report that had several required components, such as an introduction, analysis, interpretation, and conclusion (Albert, 2000; Biehler, 2007; Carnell, 2008; Sisto, 2009). The required length of the written report can also vary from five to 15 pages (Carnell, 2008; Holmes 1997; Love, 1998; Pimenta, 2006; Young, 1998).

Posters are also commonly used as a way of showcasing the final project because the information can be easily seen (Quinn, 2002; Young, 1998). Kuiper (2010) gave students detailed instructions on writing the scientific paper or poster, particularly in "what should be in a title and author panel, abstract, introduction, materials and methods, results, discussion, conclusions, references and acknowledgements" (p. 3). Kuiper also developed the “Stat2Labs” curriculum at Grinnell College, which has a focus on project-based learning and applications (http://web.grinnell.edu/individuals/kuipers/stat2labs/). Some instructors encourage their students to work on drafts of posters a week before the presentation (Dierker, et al., in press; Halvorsen, 2010). Starkings (1998, 2002) required the students to submit a poster along with an additional component: either a video presentation lasting 5 to 10 minutes, or a written paper or article.

Logistics of Enacting the Statistical Investigations. Researchers have also examined the logistics of enacting the statistical investigation, which can be a semester-long assignment (Chance, 1997; Fillebrown, 1994; Holcomb & Ruffer, 2000; Smith, 1998), a short-term study (Wardrop, 1999), a single class activity (Cook, 2008), or a pilot study (Short & Pigeon, 1998). Researchers also recommend the use of a service-learning context in enacting the statistical investigation in statistics courses (Fudge, 2008; Hiedemann & Jones, 2010; Hydorn, 2007; Nordmoe, 2007; Phelps & Dostilio, 2008;

Thompson, 2009). Statistical investigations have also been enacted in teacher education or preparation programs (Batanero, Arteaga, Ruiz & Roa, 2010; Biajone, 2006; Kazak & Confrey, 2004; Makar, 2004; Mendes, 2006). Other researchers suggested focusing on a particular concept or data, such as inferential statistics (Albert, 2000), experimental design (Mackisack, 1994), nonparametric methods (Coakley, 1996), or statistics in sports (Wardrop, 1996). Starkings (1997) recommended the use of a staged assessment (or assessment in stages) so that students can receive feedback from the instructor at various time points throughout the length of the project. Only a few researchers mentioned the need for an approval from the university's Institutional Review Board (IRB), prior to the data collection and analysis (Halvorsen, 2010; O'Connell, 2002; Thompson, 2009).

The use of technology or computer software can also facilitate the statistical investigation, particularly in the data analysis phase. Some instructors use Excel because of its availability and accessibility (Dutton & Dutton, 2005; Lee, 2005; Pimenta, 2006; Sisto, 2009). Others prefer to use specialized programs, such as Fathom (Kazak & Confrey, 2004; Makar, 2004), Minitab (Kuiper, 2010; Lee, 2005; Mackisack, 1994) and SPSS (Dierker, et al., in press; Mendes, 2006; Nordmoe, 2007; O'Connell, 2002; Pimenta, 2006; Tintle, VanderStoep, Holmes, Quisenberry, & Swanson, 2011). It should be noted that most of these computer software are only accessible in the university's computer labs because purchasing these would be too expensive for students. Although the use of technology can support the data analysis phase, Nolan (2002) found that some students have computer anxiety and that they need more technical assistance with using software packages. This finding may be less relevant today, as students enter college with more computer knowledge than they did in 2002.

Some instructors encourage their students to work in groups (Froelich, Stephenson & Duckworth, 2008; Jolliffe, 1997; Keeler, 1997). While some instructors allow the students to form their own groups (Forster & MacGillivray, 2010), other instructors randomly assign students to groups (Cook, 2008). Love (1998) allowed students to work individually, or in groups of two or three students. Others allowed various group sizes ranging from two to four students per group (Fillebrown, 1994; Halvorsen, 2010; Sadie, 2010; Smith, 1998; Zeleke, et al., 2006).

Several researchers have also suggested the use of peer assessments as a way of giving feedback to students (Bilgin & Fraser, 2007; Bulmer, 2010; Halvorsen, 2010; Lavigne & Lajoie, 2002; Sisto, 2007). Feedback from the instructors was also an important way of ensuring a successful statistical investigation (Cesar & Dias, 2006; Chance, 1997; Fillebrown, 1994; Keeler, 1997; Love, 1998; Spence, Sharp, & Sinn, 2011; Starkings, 1997). Starkings (1997) noted that

> Feedback should be given as soon possible after the project has been graded. Feedback can be negative as well as positive since students need to know their strengths and weaknesses. If a staged assessment is used feedback can be given at the end of each stage so that students know exactly what grades they have achieved up to that point. (p. 11)

Some instructors require the students to submit drafts of posters a week before the actual poster session, so that the instructor can give feedback to the students (Dierker, et al., in press; Halvorsen, 2010). This shows that feedback is important, especially in supporting students' emerging statistical reasoning.

2.1.3 Evaluating the Effectiveness of Projects

Researchers investigating the effectiveness of statistical investigations have played a role in advocating its use in statistics courses. There are many ways of

evaluating the efficacy of projects, such as using final grades, test scores, student reflection, teacher or course evaluations, and independent surveys. Some researchers use a quasi-experiment in order to compare the project-based group to a control group, while others use a pretest and posttest design to measure the learning gains.

Chadjipadelis and Andreadis (2006) found that students in the project-based group had a statistically significant increase in final grades compared with those in the control group, which shows that the project fostered students' understanding of the statistical concepts. Likewise, Smith (1998) found an increase in test scores on the midterm and final exams in the project-based course compared to the previous courses with no project requirement; however, significance tests were not performed. Spence, et al. (2011) designed their own instrument to measure students' content knowledge of statistics, and found an increase in test scores in the project-based course compared to a control group, but the difference was not statistically significant. Vaughn (2009) also designed a 33-item instrument to measure students' learning on regression and hypothesis tests. He compared the results from the cognitive measure of three groups: lecture only, "lecture + active learning," and "lecture + active learning + team projects," and found that the lecture only group was significantly lower than the other two groups. However, Phelps and Dostilio (2008) compared the performance of students who participated in a service learning project and those in a traditional project assignment, and found no significant difference between the two groups with respect to the scores from the following assessments: project 1 (first phase), final project, final exam and total grade.

Lavigne and Lajoie (2002) reported that the students who conducted a project "learned about statistics and improved their test scores (maximum = 51) from the

beginning (M = 13.22, SD = 4.17) to the end of the research (M = 21.58, SD = 5.90)" (p. 4). However, their report did not include significance tests on the increases. Tintle and colleagues (2011), used a pre- and posttest design of the Comprehensive Assessment of Outcomes in Statistics test (CAOS; delMas, Garfield, Ooms & Chance, 2006), which consisted of 40 multiple choice questions, including both descriptive and inferential statistics questions that are conceptual in nature. They found that students' average CAOS scores increased significantly ($p < 0.001$) on a matched-pairs t-test of pre- and posttests. However, these learning gains were similar to those of the control group or traditional curriculum, and they were able to detect only a slight difference in aggregated learning gains using a one-way ANOVA ($p = .093$). On the other hand, Sovak (2010) who used similar items from the CAOS test, which concentrated on regression, chi-square, ANOVA and paired t-test, found that the students who participated in a project-based course had significantly higher learning gains compared to the traditional or control group.

Nordmoe (2007) conducted a survey of students who completed a service-learning project and found that 71% of them believed that the project helped in improving their data analytic skills, but only 40% viewed that the project helped them in learning the statistics. Nordmoe concluded that the service learning project was successful in supporting students' learning and in promoting their interest in research. Rheinlander and Wallace (2011) found statistically significant increases in how students positively viewed reading and writing in mathematics courses after conducting projects. In terms of final grades, Knofczynski, Hadavas and Hoffman (2007) did not find any significant

difference in the distribution of the grades between courses with projects versus those without.

In summary, the results were mixed, but showed overall promise for the use of projects or statistical investigations in promoting students' learning. The types of research studies that have included statistical investigation can be grouped into two categories: (1) theoretical models of the process of statistical investigation, and (2) how to use or implement statistical investigation – the enactment or practice. Having the students engage in statistical investigations can be considered one of the most important components of active learning in statistics. As such, understanding how students view statistical investigation in terms of their motivation, attitudes and beliefs (e.g., helpfulness in learning statistics) seems to be one of the important research areas in statistics education. Interestingly, it is possible that not all students who are doing statistical investigations in their courses are motivated by their topic or the questions that they formulated. Furthermore, not all students may enjoy data collection or analysis.

2.2 Theoretical Framework on Motivation

This next section of the review is organized into two major research areas: (1) literature on motivation, beliefs and attitudes; and (2) statistics education and motivation. I contend that both disciplines, psychology and statistics education, have different definitions and conceptualizations of motivational constructs within and between groups. I begin by providing key motivational constructs and theories. I then examine how motivation theories are applied in statistics education. By using studies that were conducted in statistics courses, I aim to exemplify the breadth of the content and findings of the research in statistics education related to motivation.

2.2.1 Motivation, Beliefs and Attitudes

Psychologists studying motivation have operationalized it in a variety of ways. Ford (1992) defines motivation as having three psychological functions: (1) energizing or activation of behavior related to students' engagement in learning; (2) directing behavior such as choosing the course of action; and (3) regulating persistence of behavior. Similarly, Brown (2007) noted that motivation is a temporal and dynamic state which pertains to "initiation, direction, intensity and persistence of behavior" (p. vii). Scholars in the field of motivation have looked at the relationship between achievement and motivation in the following areas: self-efficacy (Bandura, 1986; Pajares, 2005; Schunk, 1991), goals (Dweck, 1986; Elliot & McGregor, 2001; Pintrich, 2000; Stipek, 1998), and values (Wigfield and Eccles, 2002).

Bandura (1986) defined self-efficacy beliefs as "people's judgments of their capabilities to organize and execute courses of action required to attain designated types of performances" (p.391). Regardless of whether a self-efficacy judgment is accurate or not, it can influence how students choose their activities. On the other hand, some students avoid tasks or activities that can lead to negative judgments of their competence, which is known in motivation research as having a *performance-avoidance goal* (Pintrich, 2000; Elliot & McGregor, 2001). Elliot & McGregor (2001) proposed a 2 x 2 achievement goal framework comprising of mastery-approach (learning for the sake of learning), mastery-avoidance (learning for the sake of avoiding failure), performance-approach (choosing activities that will show competence), and performance-avoidance goals (avoiding activities that will show incompetence).

In addition to achievement goal theory, Wigfield and Eccles' (2000) expectancy-value framework states that students' motivation and achievement are influenced by how they value a particular academic task and their expectations for success. Broadly speaking, Eccles and colleagues posited that students' beliefs on how well they will do on a particular task, defined as expectancies for success, are related to four components on how they value the task. These four components are known as the subjective task value: attainment value, intrinsic value, utility value and cost. *Attainment value* indicates whether the student thinks that doing well on the task is important or not, while *intrinsic value* is related to the students' interest or enjoyment from engaging in the task. *Utility value* links the usefulness of the task to the students' future goals, such as their career. Lastly, the *cost* factor refers to the possible explanations for why a student might try to avoid the task – for example, fear of failure, task difficulty, or math anxiety. According to this model, students' expectancies for success are positively influenced by the attainment, interest and utility value, while the cost can negatively affect their engagement with the task. The students' achievement related choices and performance (i.e., academic effort) are then influenced by the subjective task value and their expectations for success (Wigfield, Tonks, Clauda, 2009). Empirical evidence supports Wigfield and Eccless' (2000) contention that students' achievement outcomes and choices of tasks can be predicted by their expectancies for success and values. Researchers in various fields and disciplines have applied the Expectancy-Value theory in their studies (e.g., Bøe, Henriksen, Lyons, & Schreiner, 2011; Bruinsma, 2004; Durik, Vida, & Eccles, 2006; Luttrell et al., 2010; Simpkins, Davis-Kean, & Eccles, 2006).

The information provided by the Expectancy-Value theory, specifically the subjective task value framework, was used in the design of the statistical investigation in this dissertation study. For example, if students are allowed to choose a topic or question that interests them where they will investigate by collecting numerical data through a survey, then they would value the task which can potentially lead to a successful statistical investigation. However, it is also possible that the statistical investigation may not promote the task value, or the cost associated in conducting the statistical investigation might be too high for the students to engage in this activity. In this dissertation, the expectancy-value theory was particularly useful in understanding how students valued their projects and the academic related choices that they made in the various phases of the investigation, especially in how they weighed the cost of completing the project with the value that they assigned to it.

2.2.2 Statistics Education and Motivation

Researchers that focus on dispositions and motivation, however, often do not probe inside the realm of statistics education. On the other hand, several statistics education researchers have been studying the motivation, attitudes and beliefs of students in statistics courses (Dauphinee, Schau & Stevens, 1997; Gal & Ginsburg, 1994; Gal, Ginsburg & Schau, 1997). Perhaps one reason for this lack of overlap between psychology and statistics education is the difference in the way motivation and disposition are conceptualized and measured. Gal, Ginsburg & Schau (1997) noted that the lack of research in students' attitude and other non-cognitive factors can be attributed to two factors: (1) lack of theory-based work to guide the study, and (2) narrow use of research methods, especially in survey measures. One of the well-known surveys in

statistics education, with documented psychometric properties, is the *Survey of Attitudes Toward Statistics* (SATS; Dauphinee, Schau & Stevens, 1997; Hilton, Schau, & Olsen, 2004; Schau, Stevens, Dauphinee, & Del Vecchio, 1995; Schau, 2008). The SATS-36 has six components that measure attitudes: affect; cognitive competence; value; difficulty; interest; effort. Others have developed surveys that focus on statistics anxiety (Onwuegbuzie, 2000; Onwuegbuzie & Wilson, 2003; Vigil-Colet, Lorenzo-Seva & Condon, 2008), and self-efficacy (Finney & Schraw, 2003). However, all of these survey instruments reflect various conceptualizations of attitudes and motivations, and how these are measured (Ramirez, Schau & Emmioglu, in press).

The bulk of the research that has examined the relationship between motivation and statistical investigations has been quantitative in nature. Researchers have typically investigated the motivation and attitudes of students through surveys and self-report measures, with mixed results. Nordmoe (2007) developed a survey and found that after completing a service learning project, only 31% of the students reported that the project increased their interest in statistics. Knight (1990) reported that 56% of the students said that the project work was more enjoyable than the rest of the coursework, while only 31% of the students felt that it was more valuable. Knight also found that 43% of the students viewed the project work as neither easy nor hard. Vaughn (2009) reported that 87% of the students had a positive experience in the project, while the remaining minority said that they "did not feel respected by the other team members, and another student felt frustrated by the lack of work from some team members" (p. 119). Makar (2004) studied the investigations of prospective teachers and found that their degree of engagement with their topic significantly correlated with the depth of statistical analysis they presented.

Carnell (2008) used the SATS-36 (pre and post) and found no significant difference in students' attitudes (in all six components) between those who completed a project versus those who did not. However, Chadjipadelis and Andreadis (2006), who also used SATS-36 found that the students who were in a project-based course had statistically significant higher attitude scores than those in the control group, with the exception of the difficulty component. Harlow, Burkholder and Morrow (2002) developed their own pre and post survey instrument called Quantitative Attitudes, and used structural equation modeling to analyze the results. They found that students who conducted applied projects "significantly reduced their quantitative anxiety and significantly increased their quantitative self-efficacy over the course of a semester" (p. 423). Spence and Sinn (2009) also developed their own instrument called the Statistics Self-beliefs Survey and found a higher average score from the group who conducted a project than the control group, but the difference was not statistically significant.

Phelps and Dostilio (2008) compared the attitudes of students who participated in a service learning project and those in a traditional project assignment, and found no significant difference between the two groups with having a positive experience in the course. However, they did find a statistically significant higher percentage of students from the service learning group who reported an appreciation of real world experience ($p = .019$) and student development ($p = .005$), which are both related to the usefulness of the project. Spence and Sinn (2009) developed the Perceived Usefulness Survey and found that the students in the project group scored significantly higher than those in the non-project or control group ($p < .01$).

The above studies all utilized quantitative measures to analyze students' motivation. Comparatively fewer qualitative studies on the relationship between motivation and statistical investigations have been undertaken, and those that have been conducted are usually based on students' reflection or course evaluation rather than in-depth interviews or other qualitative methods. In these qualitative studies most of the students' comments were positive and indicated that the project enhanced their interest, enjoyment, and utility value of the course (Biajone, 2006; Fudge, 2008; Loi, 2002; Love, 1998; Smith, 1998; Sovak, 2010). Here is an example from Smith (1998), who reported a comment from one of the students: "projects really help us understand the material…" (p. 8). There were also some negative comments from students, and Loi (2002) pointed out that some students thought that the projects were time consuming and stressful.

Neumann, et al. (2010) conducted a mixed-methods study that looked at the effectiveness of the Data Gathering Survey, an instrument that collects survey data amongst the students themselves. To reduce bias, they hired another researcher that the students had never met who interviewed a random sample of 38 students individually. The interview data were coded and the results showed that 71% of the students said that the instrument created interest, but only 32% of them said that it was a fun activity. Still, 63% of them said that it increased the connection between statistics and concepts, and 45% of them said that it helped them understand research methods and statistics. Only 29% of them talked about increased participation, while only 21% said that it reduced negative mood states (e.g., stress, anxiety).

To summarize this section of the paper, I reviewed two literatures that are critical to extending our collective knowledge about how motivation is important for learning

statistics: (1) literature on motivation, beliefs and attitudes; and (2) application of motivational theories and measurement of motivational constructs in statistics education. This literature review showed that as students developed their statistical reasoning and thinking by engaging in statistical investigations, they also developed their motivation and attitudes. Based on the literature review, a conceptual model emerged to illustrate the relationship between statistical investigation and motivation which will be explained in the following section.

2.3 Conceptual Framework & Conclusion

Learning mathematics and statistics is a complex activity that requires attention to many pedagogical factors and influences: the learning goals, students' beliefs and motivation, curriculum design, and the assessment practices. In this dissertation, my role as a teacher, researcher and designer influenced the theoretical perspectives that guide this study. Central to this perspective is the view that understanding students' learning requires an understanding of the students' motivation because how students feel about a particular subject can have a lasting impact, long after mathematical formulas are forgotten. This suggests that it is important to take into account both the stated and implicit goals of student learning. For example, having a numerically or statistically literate society is an important goal, which can be developed by teaching mathematical and statistical reasoning, but students' motivation can greatly influence what they actually learn and how their learning is made visible.

Figure 2.1 shows the conceptual framework that guided this study to illustrate my argument that there are reciprocal relationships among the various phases of the statistical investigation and motivation. Notice the bi-directional arrows showing that motivation

leads to statistical investigation, and vice versa, and that these motivational constructs are apparent throughout the various phases of the statistical investigation. Instead of thinking about the phases of statistical investigation and motivation as making separate contributions to the development of students' learning, it is more productive to think about the dynamic and reciprocal influences of these elements.

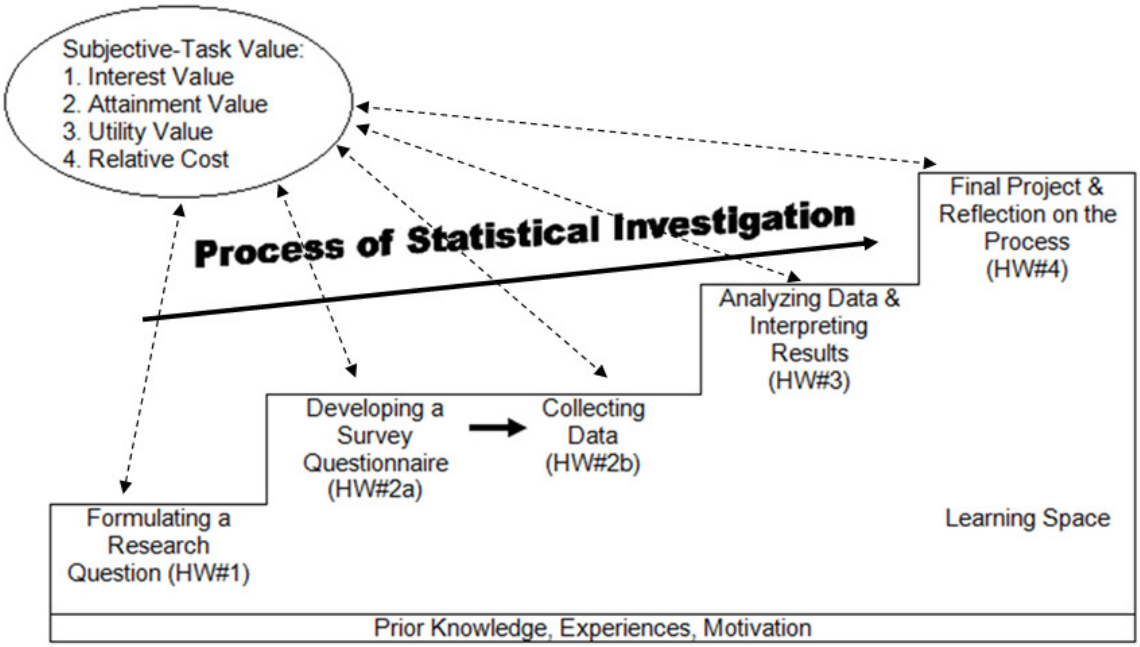


Figure 2.1: Conceptual Framework for the Statistical Investigation

This model builds on Wigfield and Eccles' (2000) Expectancy-Value Theory of motivation, particularly the subjective task value: interest or enjoyment value, attainment value, utility value and relative cost. Throughout the four phases of the statistical investigation, these subjective task values can inform or influence the students' achievement-related choices or effort in completing the task. The model also depicts a flight of stairs because Starkings (1997) suggested the use of a staged assessment (or assessment in stages) that breaks up the length of the project into phases. I used the following phases for the statistical investigation: formulating a question, collecting data,

analyzing data and interpreting results, and the final project and reflection. Each of these phases builds on to the previous one, which were based on the GAISE framework (Franklin & Garfield, 2006; Franklin et al., 2007) and the model proposed by Friel and Joyner (1997). The conceptual framework for the statistical investigation illustrates the notion of learning as a process involving the different stages in the project that build on prior knowledge, experiences and motivation. The process is generative and dynamic in that the students need motivation to move from one stage to the next in order to shape their learning.

In this literature review, I have emphasized the need to extend the collective knowledge on how students learn statistics at the cognitive and psychological levels. I have presented a conceptual framework that emerged from this literature review to illustrate the reciprocal relationship between motivation and statistical investigation. Research in statistics education recognizes the notion that motivation plays a critical role in shaping how students learn mathematics and statistics by affording particular dispositional elements to develop. In my effort to superimpose motivational theories and constructs onto conceptual and practical issues surrounding statistics education, I hope to have begun to problematize the relationship between statistical investigation and motivation. However, I point out that many statistics education researchers have drawn upon similar constructs from motivation research, though without explicitly referencing their theoretical orientation. Overlaps between statistical investigation and motivation reside in their attention to better understand the learning processes of students.

I conclude that there are potential future directions for extending work in this area of establishing the relationship between statistical investigation and motivation. As

Shaughnessy (2007) noted, “there has been very little research into students’ and teachers’ beliefs and attitudes toward statistics” (p. 1001). I propose that as researchers seek to understand the development of students’ statistical literacy, reasoning and thinking, they must integrate motivation research not only as a mediating variable but also as a key component in learning statistics.

Chapter 3: Methodology

A mixed-methods study was conducted to examine the motivation and quality of students' statistical investigations or projects. Because the main bulk of the data in this study were students' writing, including over 200 documents, I used both qualitative and quantitative methods to analyze it. In addition, I conducted student interviews and used qualitative case study methods in order to triangulate the information from stduents' writing, and to uncover the students' motivation, particularly the subjective task value in Wigfield and Eccles' (2002) framework. This chapter outlines the context of the study, participants, data and instruments, and method of analysis of students' statistical investigations and motivations.

3.1 Site, Participants & Researcher Positionality

3.1.1 Research Site and Context

This study was conducted at California State University X (CSUX; a pseudonym) in a course called "Mathematical Reasoning" (Math 1). This course is offered in fulfillment of the General Education (G.E.) requirement for graduation. A majority of the students who take this course do not have a specific math requirement, and come from liberal arts majors (e.g., communication studies, education, music, etc.). Math 1 is offered by the mathematics department and it is the department's most popular course, with up to 700 enrollments per semester. CSUX serves approximately 29,000 students, of which 83% are undergraduate students. Below are the CSUX student body demographics, in terms of gender and ethnicity, which shows a very diverse student population.

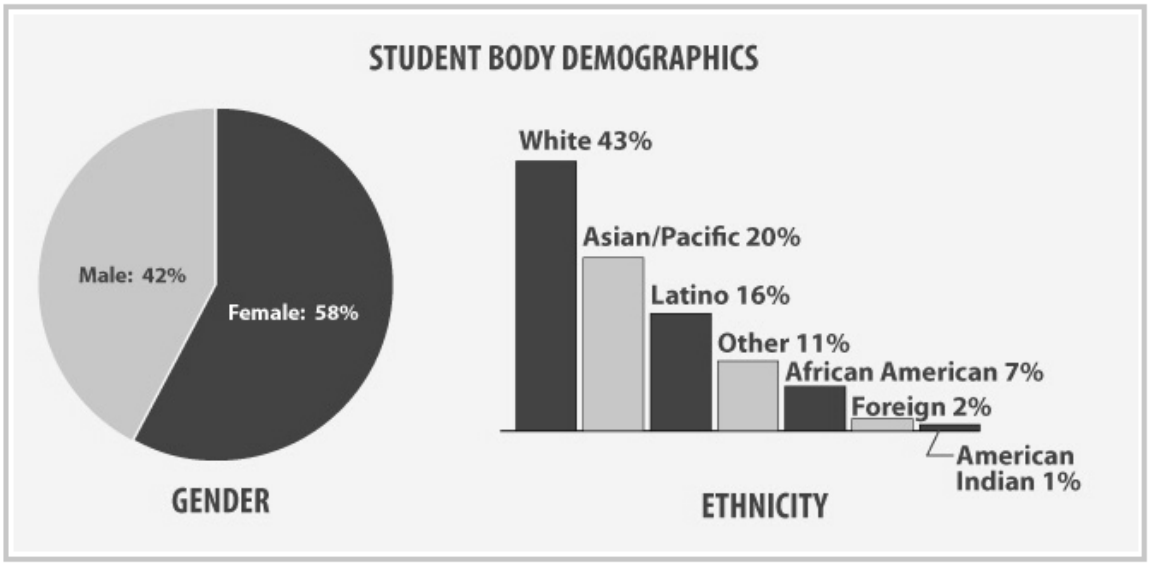


Figure 3.1: CSUX Student Body Demographics

The advantages of using a Math 1 over an Elementary Statistics (Stat 1) course for this study are as follows: (1) students who do not have a specific math requirement are more likely to have a weaker overall mathematical and statistical content knowledge since the pre-requisite for Math 1 is elementary algebra while Stat 1 students are required to pass an intermediate algebra diagnostic test; and (2) students with weaker math skills can potentially gain deeper understanding of statistical concepts by the end of the study, since the focus of this course is on descriptive statistics alone, and excluding the inferential part. Furthermore, promoting statistical reasoning in a mathematical reasoning course might have a long-term impact on students' statistical literacy and overall interest towards statistics given that they will be unlikely to have opportunities to study statistics after taking this course.

In addition, I chose this research site to conduct this dissertation study because I was teaching two sections of Math 1 during the Spring 2010 semester. Prior to this study, I started designing a set of activities centered on statistical investigations, in which I piloted these homework activities during the 2008 to 2009 academic years, while I taught

the same course. I further developed and finalized the materials during the Fall 2009 semester, in preparation for the actual data collection for this study. I also interviewed one of my students from the Fall 2009 semester after completing the course, which helped me in finalizing my interview protocol. Approval for conducting this dissertation was granted by the mathematics department chair, the participants, and the Institutional Review Board at UC Davis.

3.1.2 Participants

There were a total of 73 students who enrolled in the two sections of Math 1. The demographics of the combined section consisted of 68% females (50 out of 73), and approximately 80% of the students were in their first and second year in college. The ethnicity of the students were 37% White, 19% Mexican American, 11% African American, 8% Asian, and 20% mixed ethnic origin, while the remaining 5% declined to state their ethnic origin. The majority of the students (80%) had declared majors, while 20% were undeclared at the beginning of the semester. Some of the students were majoring in communication studies (8%), criminal justice (8%), child development (5%), liberal studies (5%), English (4%), nursing (3%), sociology (3%), and other courses such as anthropology, dance, journalism, photography, public relations and social work. While it is common for students to work while going to college, 41% of the students were unemployed (29 out of 70; 3 students declined to state their employment status). Of the students who were employed, 44% of them had part-time employment, with an average of 18.1 hours per week of work (ranging from 15 to 20 hours per week, inclusive), while 56% of them worked for more than 20 hours per week, with an average of 31.6 hours per week (ranging from 24 to 47 hours per week, inclusive). Some of the students worked as

a cashier at grocery stores, sales associates at retail stores, hostess or servers at restaurants, assistants in an after school daycare. A few of them worked in other capacities such as legal assistant, research assistant, assistant managers and customer service representatives.

There were seven interview participants that were selected from the sample of approximately 50 students who fit criteria outlined below and completed the statistical investigation and received a final grade for the course within the range of 76.5% to 92.4% (C+ to A-) inclusive. Emails were sent out to the sample of students within two weeks after the final grades were submitted, which contained an invitation to participate in an hour long interview about their experiences in conducting the project or statistical investigation. Although it appears that the seven students self-selected themselves to participate in the interview, the students were already pre-selected during the invitation phase because they fit a set of criteria. The first criterion was the completeness of the data. Students who had completed at least three of the four phases of the statistical investigation were also selected to participate in the interview, as long as they completed the final project of the statistical investigation. This was because the final project included a self-reflection of the students' motivation and learning. Additionally, the following data were also required: Interest Inventory for their background information, and the pre and post Basic Statistics Exam for the assessment of their content knowledge.

The second criterion was the final grade, concentrating in the middle of the distribution (B grade), because these are the students that are representative of the typical student in the course. The last criterion was the quality of the statistical investigation, in which I briefly examined the positive and negative attributes of their topic or research

question, data collection, analysis and interpretation, and the overall success or failure in their statistical investigation. I selected a mix of participants that had good quality projects and those with less successful statistical investigations in order to better understand students' motivations in completing the task while looking at the quality of their work. This last criterion was perhaps the most important one in criterion sampling because it informed the questions that I should ask them in the interview. I sent emails to 50 students who met the criteria to participate in this study, and only seven students accepted the invitation to be interviewed. Fortunately, the seven volunteers happened to represent a wide variety of investigations in terms of topic and quality of the investigation. Table 3.1 shows the description of the interview participants.

Table 3.1: Description of Interview Participants

Student*	Gender	Age	Ethnicity	Year	Major	Prior Statistics Courses
Hannah	F	21	Filipino	2	RPTA: Recreation Parks and Tourism Administration	No
Francine	F	23	African American	3 or 4	Sociology (and Nursing)	Yes, in high school
Isaac	M	21	Mexican American	1	Dance Major (and International Bussiness)	Yes, in high school (descriptive only)
Thomas	M	19	Vietnamese	1	Business (Undeclared during the semester)	Yes, in high school (descriptive & inferential)
Zach	M	19	White	1	Kinesiology	No
Grace	F	19	African American	1	Nursing	Yes, in high school (descriptive only)
Quinn	F	20	African American	3	Sociology (and Pre-law)	Yes, in junior college, but did not pass (D-)

*All names of students are pseudonyms to preserve their confidentiality and anonymity.

The interview participants were from various majors that are typical of most Math 1 students, with ages ranging from 19 to 23 years. Five out of the seven students

mentioned that they have some background in statistics, mostly descriptive statistics from high school, while only two students said that they did not have prior statistics courses.

3.1.3 Researcher Positionality

This dissertation evolved from the work that emerged from my own teaching practice and curriculum design conducted in Math 1. As a teacher researcher, I wanted to study some aspect of mathematics and statistical learning by designing an intervention. As a designer, I used research from mathematics and statistics education to inform my designed intervention. After studying the statistical investigations of my students, I realized that subsequent iterations were needed in improving the designed intervention; this approach is known as design-based research methodology, which is what I used in the initial stages leading up to this dissertation study. According to Wang and Hannafin (2005), design-based research is

> a systematic but flexible methodology aimed to improve educational practices through iterative analysis, design, development, and implementation, based on collaboration among researchers and practitioners in real-world settings, and leading to contextually-sensitive design principles and theories (p. 6)

This methodology supports the production of design ideas, similar to what I have been doing in improving the statistical investigation set of activities. As a teacher, designer and researcher, I was well-positioned to study the ways that the designed intervention interacts with students' learning and motivation. In order to understand the reciprocal relationship between statistical investigation and motivation of college students, I focus on the latest iteration of the designed intervention that I have developed for this

dissertation study, rather than showing the evolution of the curriculum design from the previous three semesters.

Because this is a mixed methods study with a larger percentage on qualitative methods, it is important to discuss my personal assumptions and biases that I bring to this dissertation research. I realize that the interpretation of the qualitative data that I analyze depended on my own background. I once worked as a substitute math teacher in high school, so the attitudes and motivations of teen age students, including college freshmen and sophomore students, are familiar to me. I attended UC Davis and completed a master's degree in statistics, which qualified me to teach as an adjunct faculty at CSUX. The first course that I taught at CSUX was an elementary statistics (Stat 1) course back in the Fall semester of 2005. Since then, I have taught other courses including Math 1, and have familiarized myself with the students who take this course. I have a strong belief that statistical reasoning should be part of a mathematical reasoning course, since most of the students in Math 1 are not likely to take a statistics course. This is one reason why I am drawn to the concept of using statistical investigations in fostering statistical reasoning and motivation. My background and beliefs are my lenses, and I recognize my position as an instructor can bias my interpretation of their narratives. However, both the qualitative and quantitative data have been carefully coded and analyzed to ensure the validity and establish trustworthiness of the results.

3.2 Data Collection and Instruments

Data were collected from January to June 2010; the time span covered a Spring semester, plus a month after the students received their final grades. The students in this

research study conducted a statistical investigation based on their selected topic. The students were involved in the formulation of the research question, data gathering, analysis and interpretation of results, which provided them with authentic and familiar contexts as opposed to solving textbook problems. I also conducted an interview of the participants two to four weeks after the end of the semester, in order to triangulate the research findings (Merriam, 1998). Below is a list of the sources of data for this study, followed by a detailed description:

- Interest Inventory – Possible Topics for Statistical Investigation
- Statistical Investigation (4 homework assignments)
- Student Interviews
- Pre & Post Test: Basic Statistics Exam

3.2.1 Interest Inventory – Possible Topics for Statistical Investigation

I asked the students to identify potential topics for their Statistical Investigation. I designed an "Interest Inventory" worksheet (Appendix A) where the students could generate possible topics based on the activities, hobbies, sports, or career interests that they might have had. This also became an "icebreaker" during the first week of school, or a way for the students to get to know their classmates as they shared their interests. Previous enactment of statistical investigations showed that topic selection was crucial in the successful completion of the homework tasks. Wigfield and Eccles' (2000) expectancy-value framework guided the design of the "Interest Inventory" to capitalize on students' interest which might influence how they valued their statistical investigations. Still, the designed "Interest Inventory" worksheet did not guarantee that the students picked a topic from this list, nor that their chosen topic yielded datasets that

were fruitful for their statistical investigation. The information from this worksheet helped establish the students' interest in the topic that they chose.

3.2.2 Statistical Investigation

The students wrote four homework assignments describing the activities in each of the components of a statistical investigation and a reflection at the end. They were given twelve weeks to complete the inquiry project, and throughout that time, two or three students presented various phases of their investigation to the class (around 5 to 10 minutes). The homework assignments for the statistical investigation part are as follows: (1) *formulating a question;* (2) *collecting data;* (3) *analyzing the data and interpreting the results;* and (4) *final project and reflection on the process*. These four components, based on the Guidelines for Assessment and Instruction in Statistics Education (GAISE) report, provided the students a scaffolding structure to conduct research and empirical investigations to develop statistical reasoning and literacy (Franklin & Garfield, 2006; Franklin et al., 2007), similar to the model proposed by Friel and Joyner (1997).

In order to simplify the data collection and maintain the analysis at the student level, these statistical investigations were conducted by the students individually instead of allowing them to do this in groups. The students submitted the homework assignments for the statistical investigation through an online course management system, similar to Blackboard. Feedback was given to the students a week after they have submitted their work. Below is a brief description of each task, and Table 3.2 shows the deadlines and summary of required pages. Appendices B to E included the specific homework assignments in conducting a statistical investigation, as well as the rubrics in grading these assignments.

Statistical Investigation Homework #1: Formulate Questions. The purpose of this homework was for students to start thinking about their project for the semester, which were then was used for the next three assignments: homework #2: *data collection,* homework #3: *data analysis & interpretation of results, and* homework #4: *final project & reflection*. The students were required to write two to five research questions or topics that they would investigate by collecting numerical data through a survey, and provide a rationale for the study. The quality of the questions and their relevance were graded in this phase of the statistical investigation. The students were encouraged to select topics that they were interested in or familiar with – for example, the students might use this project as an opportunity to know more about a particular major, career or job. They were also allowed to use survey data from their work or another project, as long as there were numerical variables in the data. At this phase of the statistical investigation, the students were encouraged to start thinking about the survey questionnaire and the appropriateness of the variables that they would need. For instance, if Student A wanted to keep track of her weight every hour for the next 30 hours – this example of a project that was not appropriate because it was trivial, and it would not yield enough variability in the data. On the other hand, if Student B wanted to ask 30 people about their weight, and if they exercise or not – this was appropriate and could possibly yield interesting data. This phase was important because formulating questions for statistical investigation can help students in developing their statistical thinking and literacy (Whitin, 2006). Feedback was given to the students to help them in the topic selection and in preparing them for the next homework. Students were also allowed to revise their research questions or topics.

Statistical Investigation Homework #2: Data Collection. Students were required to describe their proposal of the data collection for their research project. The students were required to develop their survey questionnaire and collect both categorical and continuous variables so that they would be able to show their understanding of the different measures of central tendency and dispersion, while comparing these continuous variables between categorical groups. This requirement was also emphasized in the feedback, especially if the student did not include continuous variables in their survey questionnaire. Secondary data were not allowed since most large-scale datasets would be more appropriate in a "formal" inferential statistics course. In my previous enactments of the statistical investigation activity in my pilot work I allowed the students to use secondary data from large datasets or census data, which yielded disappointing results when students tried to apply statistical reasoning so I decided to have students collect their own data for the investigations described here.

Statistical Investigation Homework #3: Data Analysis and Interpretation of Results. In this phase of the study, the students conducted the data analysis and showed two or more visual displays of data (e.g., tables, graphs, bar chart, box-and-whisker plot, etc), as well providing the interpretation of the relevant statistics. The feedback focused on addressing the accuracy of the analysis and interpretation. The students were allowed to revise this homework and include the revisions in the next one. They also had to explain possible biases inherent in the data, or limitations in the interpretation of the analysis, as an entry point towards statistical reasoning. I had learned from Students from previous semesters who had used secondary data from large datasets or census data that they found it difficult to understand the potential biases in the data. Thus, in this latest

iteration of the designed activity, I made a conscious decision to only allow primary data in the form of a survey that the students collected themselves.

Statistical Investigation Homework #4: Final Project and Reflection. This homework was a culmination of the previous homework assignments with a discussion and reflection in the end. The students were given the opportunity to revise the previous homework based on the feedback that they received. In the "Discussion and Conclusion" portion of this homework, the students summarized the results of the study based on the data, and explained how the results might change or remain the same if a larger sample was obtained or if the data were collected at another site. The students also discussed their level of certainty about their conclusions based on the evidence that they had. The design of this activity was informed by the research base on informal inferential reasoning, specifically Makar and Rubin's (2009) framework. Additionally, the "Reflection" portion of this homework included a discussion of what the students learned or liked about this project, and how they might change or improve this study.

Table 3.2: Summary of the deliverables for the statistical investigation

Homework Assignments	Description of Students' Writing Requirements
1. Formulating a question (deadline: Week 4)	Two to five research questions or topics that they want to investigate by collecting numerical data through a survey, and provide a rationale for the study. Students were encouraged to select topics that they are interested in or familiar with. (1-2 pages)
2. Collecting data (deadline: Week 7)	A description of how they will collect data for their research project, and the sample size (minimum of 30). Survey instrument should have both categorical and continuous variables. (1-2 pages)
3. Analyzing the data and interpreting the results (deadline: Week 11)	Show 2 or more visual displays of data (tables, graphs, bar chart, box-and-whisker plot, etc.), and the interpretation of each display. Explain possible biases inherent in the data, or limitations in the interpretation of the analysis. (2-5 pages)
4. Final project and reflection on the process (deadline: Week 15-16)	Compilation of previous assignments organized into the following: Introduction; Methods; Results and Analysis; Discussion; and Reflections. (3-8 pages)

The students had an opportunity to present their statistical investigations in class for approximately 5-10 minutes. This was an informal presentation of their progress

towards completing their statistical investigation. However, the presentations were not included in the analysis because no new information emerged from this data source that was not included in the written report.

3.2.3 Student Interviews

Merriam (1998) suggested several ways to triangulate data, one of which is through interviews. Seven students participated and they described their experience with the statistical investigation that they completed. The semi-structured interviews consisted of their background and follow-up questions on their academic progress (e.g., if they were planning on taking statistics courses), as well as questions about their motivation or level of engagement with their statistical investigation. For example, I asked the students if the statistical investigation was helpful to them or not. Interviews were digitally recorded and were transcribed by the author.

In the initial stages of writing the interview questions or protocol, I relied heavily on the four components known as the subjective task value: attainment value, intrinsic value, utility value and cost. I also had to remind myself that this study was not designed to generalize or model a relationship between motivation and the task; rather I wanted to explore the students' perception, feeling or thinking about their project in relation to their motivation toward their project or task, as evidenced by the meaning-making process that they narrated during the interview. Appendix F includes the student interview protocol, which I piloted with another student and then finalized. The questions in the protocol were organized with the following categories or constructs: background, attainment value, intrinsic value, cost, utility value, and reflection questions. However, in order to

sustain the conversational flow of the interview, I changed the order of the questions accordingly.

The interviews were scheduled to last approximately 45 to 60 minutes, which took place in my office at CSUX, or at the university cafeteria where one of the students worked. Each interview was structured into three parts: (1) background experiences with math and statistics; (2) an artifact-driven interview of the statistical investigation using the four homework assignments as a guide or to stimulate recall; and (3) a reflection on their overall experience with the statistical investigation. Instead of asking each question in the protocol, I let the interviewee's responses guide the flow of the conversation (Seidman, 2006). In particular, students' response to "*Tell me about your experience with this project*" guided the order of the questions in the second part of the interview. Having the four homework assignments on the students' statistical investigation also facilitated the interview.

To ensure the validity of the data, I conducted the interviews two to four weeks after the students received their final grade in class. At the beginning of the interview, I explained to them the objectives of the study, and that the participants could stop the interview at any time. At the end of the interview, I also gave them a copy of an information sheet that was approved by the IRB. Furthermore, I explained that their participation in the interview would not affect his or her academic standing, nor would it affect my position in the university.

3.2.4 Pre & Post Test: Basic Statistics Exam

I administered pre and post tests to assess students' statistical knowledge. The tests contained items similar to the instrument *Statistical Reasoning Assessment* (Garfield

and Gal, 1999). Since Math 1 is not a typical first course in statistics and inferential statistics were beyond the scope of the class, it was not appropriate to use the *Statistical Reasoning Assessment*. Thus, I selected 20 multiple choice questions from a test generator that came with the textbook for this class. The instrument was called *Basic Statistics Exam*, which pertain to the following main ideas: visual displays of data, measures of central tendency (e.g. mean, median, mode) and dispersion (range), relative position (quartiles), normal distribution (z-score), and regression equation (see Appendix G for the instrument). All of these topics are appropriate for this course, which are included in the *Mathematical Ideas* textbook (Miller, Heeron, Hornsby & Morrow, 2007). The exam was given to the students during the first few weeks of the semester (pretest), and then towards the end of the semester (posttest). Students had opportunities to learn descriptive statistics from the class lectures and their investigations.

3.3 Data Analysis

There were two phases of analysis in this study. In the first phase, I looked at all of the investigations that were generated by students in two sections of Math 1 in the Spring 2010 term. I analyzed each investigation according to the topics students investigated, the types of variables that they used in their investigation and the quality of the final assignment. In the second phase I used the interview data from seven individuals to understand their motivation for the investigation in terms of how they valued it and how much time and effort they expended in completing it. Below is a detailed description of the following data analytic methods used in this study: content analysis, case analysis and interview coding, and statistical analysis.

3.3.1 Content Analysis

Because the bulk of the data in this study were students' writing, with approximately 240 documents (60 students each had to submit four written assignments), both qualitative and quantitative methods were used. A content analysis was conducted to evaluate the quality of each component of the statistical investigation. I examined the students' statistical investigations after the semester was over, and I used Atlas-ti in compiling the qualitative codes. First, the data were coded using "loose" analysis (Miles & Huberman, 1994). The "loose" analysis can be considered as the exploratory stage of the data analysis because the documents were approached with an open mind while allowing the recurring themes or categories to emerge directly from the data. For example, in the first assignment, the students were required to write two to five research questions or topics, which I then categorized into various topics of interest (e.g., time allocation, money allocation, food or health).

Second, a "tight" analysis was also used because the statistical investigation had a four-part structure with writing prompts that the students needed to address. For example, in the second assignment, the students were required to describe their proposed method of collecting data, which I then categorized into various types (e.g., random sampling, convenience sampling via online, convenience sampling in the classroom). I used the constant comparative method to generate codes for the data because, as Merriam (1998) noted, "devising categories is largely an intuitive process, but it is also systematic and informed by the study's purpose, the investigator's orientation and knowledge, and the meanings made explicit by the participants themselves" (p. 179). Thus, I adjusted the codes depending on the need to merge codes when sparsely related themes emerged, and

other times, I had to split codes in order to refine the categories when a large frequency of the data were coded into a broad theme. The use of the Atlas-ti software facilitated this iterative and recursive process of coding in qualitative data analysis.

3.3.2 Case Analysis & Interview Coding

I used a qualitative case study method (Yin, 2009) to explore the statistical investigations of the seven interviewees, juxtaposed with their interview data. The interview data were transcribed and analyzed qualitatively through the use of Atlas-ti software, which helped in keeping track of the codes. In the first phase of the analysis, I went through every statement in the interview transcript and selected statements relevant to the constructs in the expectancy-value theory (Wigfield & Eccles, 2000). I coded the relevant statements that focused on the students' experiences when conducting the statistical investigation. In the second phase, I analyzed the individual students' interview transcript while simultaneously looking at the content of the statistical investigation because this was also an artifact-driven interview. This phase allowed me to capitalize on both documents in order to examine some of the interesting features that served as evidence of the students' statistical reasoning and learning. The last phase of the analysis was the synthesis of the coded interview and the artifact (statistical investigation), which resulted in chapters four and six.

3.3.3 Statistical Analysis

The codes that were developed in the qualitative analysis, specifically from the content analysis, became the categorical variables in the quantitative analysis. For example, these variables included the types of questions or topics; the quality of the

survey instrument that the students developed and used; the adequacy of the statistical investigation; and the types of variables that students used in their analysis. The adequacy of the statistical investigations was judged based on the accuracy of the graphs and descriptive statistics, relevance of the graphs and analysis presented, and their interpretation. Atlas-ti reported the frequencies of each code or category, which were then transferred to an Excel spreadsheet to facilitate the data analysis. Chi-square tests of independence were performed on two main categorical variables to test the association. In addition, descriptive statistics such as the mean, standard deviation, frequency counts and percentages were obtained, when appropriate.

Quantitative methods were used to analyze the Basic Statistics Exam, which consisted of 20 multiple choice questions. The pretest was administered to the students during the fourth week of the semester. For the posttest, the same instrument was given to the students after they had completed the data analysis phase of the statistical investigation (homework #3), at approximately the eleventh week of the semester. The data were then coded as follows: 0 for errors and 1 for correct responses. Cleaning the data set was also administered in order to separate the students who completed the project and those who did not. The students who had missing data on at least 50% of the items on either the pretest or posttest were identified. Data from 21 students were removed from the analysis of the exam because of incomplete data. The table below is a summary of the groups.

Table 3.3: Number of students by project completion and exams

	Project	Without Project	Total
Complete Pretest & Posttest	42	10	52
Incomplete Pretest & Posttest	18	3	21
Total	60	13	73

Reliability analysis and descriptive statistics on the overall scores were obtained. Next, a paired t-test was conducted on the pretest and posttest scores of the 42 students who conducted projects, and then the results were compared with ten students who did not do a project. Learning gains were calculated as the difference from pre to post: $d_i = y_i - x_i$ where y is the posttest score and x is the pretest score. The learning gains of students who did not complete the project were compared to those who completed the project. Lastly, item analyses were conducted to better understand students' performance on the test. A McNemar's test was administered to determine the association between pre and post tests at the item level. The quantitative analyses were performed using Excel, Minitab 16, and R.

3.4 Ethical Considerations & Trustworthiness

All students were informed at the beginning of the semester that their project or statistical investigations would be part of this dissertation research. The syllabus informed the students that the points for quizzes and projects would be added up and counted towards 20% of their final grade. The schedule in the syllabus also included the deadlines for the four phases of the project, as well as the dates when the online quizzes were due. There were four deliverables for the project, five scheduled quizzes, and one surprise quiz, where each item was worth ten points each, adding up to a total of 100 points. This means that the students could still pass the class without having to complete the statistical investigation because it was actually less than 10% of the final grade. Although I did not explain this to the whole class, some of the students were able to

figure this out towards the end of the semester. However, if a student wanted to get an A in the course, then the statistical investigation was required.

The IRB also approved this study because most of the freshmen students in this course were already at least 18 years of age. The students were informed of the confidentiality of the research documents in accordance with the law and University policies. The audio-recordings were kept anonymous and confidential. Students' real names do not appear in any documents, and will not be shared at conferences where this research is discussed. Lastly, the interview participants were informed that there were no consequences for declining to participate in this study, and that they could refuse to participate in or withdraw from this study.

In order to establish trustworthiness, I discussed my positionality as a teacher and researcher. I provided adequate information about participants. I have asked several people in the dissertation research meetings to verify the coding, findings and interpretations to ensure accuracy and validity.

Chapter 4: An Example of a Statistical Investigation

The purpose of this chapter is to provide an illustration of a statistical investigation from one of the students in class. In order to explore the first research question (what do students' statistical investigations look like based on their written work during the four phases of the investigation?), I drew on data from one of the students who had a robust account of her experiences in conducting the statistical investigation. The fact that Hannah had completed all four phases of the statistical investigation as evidenced in her written work (from the homework assignments) and that she was articulate about the meaning of these experiences (from the interview) made her case very helpful in examining the process that she went through with the project. Another purpose of this focused analysis of a single case study was to explore Hannah's motivation and learning throughout the various phases, in the context of her background and interest in the topic. This case was not typical of most students in class because she was very passionate about the topic that she chose for the investigation and she was able to relate this project to her personal interest. This chapter discussed deep analysis of Hannah's work which allowed rich descriptions and nuances that might have been overlooked if I only show the results from all 60 students.

4.1 Hannah's background

Hannah was a second-year student majoring in recreation parks and tourism administration (RPTA). Her project was about the amount of money that people spend in attending baseball games and concerts; this particular topic was very interesting to her because of her major. She also worked at a local baseball organization, Windstar (pseudonym), which informed her topic selection. She said: "*I usually work two games at*

home stand... so not a lot. But... I'm actually doing a work experience there too, so I'll be there more often." Her career goal after graduation was to work as an events coordinator for a sports organization or a baseball team.

Although Hannah had never taken a statistics course, she had taken a class in her major that required a project about managing a sports organization or group. Her project was about analyzing the performance of a fictional sports group, which involved some data analysis. She said, "*I evaluated a little league... workshop... like a baseball workshop for little leagues. And so I evaluated that program, and you just evaluate how they're doing in their running skills or base stealing skills, hitting skills, pitching skills, and all that stuff. And you just input data... same thing, input data and you talk about your results*." Note that this RPTA project required very little math and some exposure to using Excel, which worked to her advantage when it came to the data analysis for the Math 1 course, because Hannah's previous math experience had not required her to do any data collection and analysis. She had taken only the usual math courses in high school and some basic courses in college.

Hannah's grades in her math courses in high school and college had been passing, averaging Cs in most of her classes, despite her struggles with it. She said: "*It has always been a challenge, math for me. But I mean, I passed all my math classes in high school, but I would always average out in the end... with a C.... But it was always a challenge for me*." She said that the math placement test had put her in the elementary algebra course during her first year in college, but since she had actually taken a precalculus course at a community college previously, it helped her. Still, Hannah did not see herself as a math person and disliked math. In particular, she found this math course (Math 1) challenging

because it was different from her previous math courses. She said, "*I don't know, it was weird 'cause it wasn't like algebra... and I'm used to the algebra questions... not so much of the word problems... yeah, I'm not very good at word problems*." She also said that she had never taken a statistics course, and had only seen some of the material from her algebra and geometry classes in high school. Thus, Hannah had had very limited exposure to statistical concepts prior to this course. And because her major did not require her to take a statistics course, this course was her last math class before she graduated. This background is a typical scenario for most of the students who take Math 1, and Hannah was just one of the many students who are taking this course to satisfy the General Education requirement.

4.2 Hannah's Statistical Investigation & Motivation

Hannah was successful in completing the four phases of the statistical investigation, and her level of motivation was quite high because of her interest in the topic. She initially proposed a wide range of topics that were interesting to her, and she finalized her topic on the attendance and cost of going to two major entertainment events: concerts and baseball games. She was able to collect her data through a survey and to analyze and interpret the results adequately. In particular, her written report showed evidence of her statistical reasoning as well as the development of her logical argument. Below is a description of the various phases of the statistical investigation based on what she wrote on her assignment, juxtaposed with Hannah's motivation as evidenced in the interview.

4.2.1 Hannah's Proposed Topics (HW#1)

For the first homework assignment, the students were required to provide two to five research questions or topics of their choice that interested them. They were also required to write a rationale by providing an explanation as to why it is important to answer these research questions or investigate these topics. The purpose of this assignment was to get the students to think about the project that they wanted to focus on, so as to identify the most fruitful research questions or topics that were appropriate to the statistical investigation. It is important to note that there was no "right" or "wrong" answer to this first assignment, which allowed the students flexibility in exploring various topics. However, the instructions, writing prompts, and the rubric provided the students some guidance on the requirements for the assignments (see Appendix B for the handout that has the instructions and scoring rubric).

Hannah proposed five topics that could be answered by collecting numerical data through a survey. She did not propose research questions, but instead wrote several topics. These were (1) attendance and cost of going to concerts; (2) plans of graduating students; (3) number of students who go to baseball games; (4) distances between ballparks in various cities; and (5) diversity at school. All of these topics were appealing to her, because she wrote that she was interested in each of the topics, particularly baseball, which she identified that she had a passion for. However, she did not provide a rationale for the various topics, or why it was important to investigate these, which was one of the requirements of the assignment.

For three out of the five topics, she included one or two questions that might go in a survey questionnaire. She provided an example of a question with several answer

choices or categories that respondents might choose, after stating the topic. Below is an excerpt of what she wrote on her first assignment:

> 1. Ask students (50+) how many times they attend concerts annually. I am interested in finding out the amount of concerts they attend and the amount of money they spend per concert they attend. There will be questions about the amount of times they attend and the average amount of money they spend. I will come to a conclusion with results and relate it to the status of our economy.
>
> EX: How many concerts do you attend every year?
> A. 0-2
> B. 3-5
> C. 6-8
> D. 9 or more
>
> On total, how much do you think you spend on these concert tickets for the year?
> A. $0- $75.00
> B. $76.00- $150.00
> C. $151.00- $250.00
> D. $251.00- $300.00
> E. $301.00 or more
>
> 2. I am interested in finding out what students plan on doing after they graduate from [CSUX].
> EX:
> After college, what are you most likely to do?
> A. Travel
> B. Move back home with my parents
> C. Find a job
> D. Grad school
> E. None of the above
>
> 3. I have a passion for Baseball. I am interested in finding out how many students attend baseball games during the season (all levels of baseball; professional or college)
> EX:
> During the season, how many baseball games do you attend?
> A. 0-5
> B. 6-11
> C. 12-17
> D. 18-23
> E. 24 or more

Although the survey questionnaire was not required at this particular phase of the statistical investigation, it was apparent that Hannah was already thinking ahead and chose to include the potential survey questions as a way of showing some clarity on what she wanted to find out. This is helpful in understanding her second topic, "finding out what students plan on doing after they graduate," because the categories that she provided clarified her objective of finding the frequencies or percentages of each choice. If she had not included this potential survey question, this particular topic could have been interpreted as qualitative research due to its broader scope. Thus, Hannah was paying attention to the objective of this particular phase of the statistical investigation, which was to get her thinking about topics that could be collected through a survey.

However, she did not provide survey questions in all topics, particularly in the last two topics. Below is what Hannah wrote on her fourth and fifth topics:

> 4. I am interested to find out the distance between ballpark to ballpark if I were to start off my road trip in San Francisco (AT&T Park; SF Giants) to New York (Citi Field (NY Mets). Colorado (1), Illinois (2), Ohio (2), and New York (2) are states that have ballparks and are on the path of my road trip.
>
> 5. Students that come into my work are of very diverse population. I am interested in finding out how diverse by asking (with their permission) their ethnicity.

The fourth topic, on distances between ballparks in various cities was very different from the others. It appeared that this particular topic might be similar to what she had seen in math textbooks because it involved measuring distances. During the interview, I asked her what she thought about the other topics that she proposed and eliminated. Hannah explained that she was intrigued by the fourth topic, but then it might be difficult to obtain the data on that topic. She said: "*Well, 4—that was just off the top of*

my head, and I didn't know how I was gonna do that. So I was like, "maybe not, maybe I shouldn't do that" 'cause I have no idea how I would do that, thinking back on it now."

The last proposed topic about diversity was something that Hannah was interested in because of her experience at her work on campus. She said, "*There's a lot of people that go in there that's very diverse, so I just want to see... what percentage are this race, or that ethnicity*." However, it was not something that she was passionate about, which appears to be the reason why she did not select that topic. Notice, too, that the way that Hannah wrote this topic is unclear because she did not actually write that she was interested in finding the percentages of each ethnic group; evidence which further supports the notion that her ideas about this topic were not well formed.

As for the second topic, plans of graduating students, she explained in the interview that she did not choose this topic because it was something ordinary, and that other students might end up selecting this for the project. She said, *"With number 2, I figured everyone would wanna do something like that, so I kinda just didn't do it."* It is possible that the survey question and the choices that she presented (travel, move back home with my parents, find a job, or go to grad school) were things that she was thinking about at that time, because Hannah had transferred the previous semester from junior college to the 4-year university, and it appeared that she was looking forward to completing her degree. Her comments from the interview made it clear that she wanted a topic that would make her investigation distinctive.

Out of the five topics that she proposed, she was very interested in the first and third topics, about attendance and cost of going to concerts and baseball games, because they were somewhat related to her RPTA major and her passion for baseball. At the

beginning of our interview, when I asked her what came to mind about the project, she said, "*Well, I knew right away what I wanted to do, even though... you asked for three or four different ideas... but I knew, I think, I wanted to do this right away because it was in my area of interest. And it makes it easy for me to collect the data and explain probably the results*." This shows that Hannah was genuinely interested in the topic that she chose, and that it gave her a good learning experience that she could use for her future career. She said, "*Honestly, I liked doing this project because, like I said, it was in my area of interest. And it kind of given me more experience in doing something similar, something like this. 'Cause I know that I can use it with my job*." Throughout the interview, she expressed positive feelings on the project: *"...it took time away from just doing math... and do something interesting and fun*." She believed that doing this project had given her an opportunity to learn more about math and statistics, as well as to better understand an area that was important for her future career in sports-related business. This shows that she was highly motivated to work on the statistical investigation because of her interest in the topic, and she also realized the usefulness of the task in her future career or job.

4.2.2 Hannah's Survey Questionnaire and Data Collection (HW#2)

As mentioned before, Hannah's final topic looked at a combination of topics 1 and 3—attendance and expenses at baseball games and concerts. Her survey questionnaire had seven questions: two questions on concerts, two questions on baseball, and three demographic questions (gender, age, and major). She had a question on attendance (the number of concerts or baseball games) and the amount of money spent on these events for items such as ticket expenses, travel, and food. She provided categories for the number of concerts or baseball games people had attended during the past year,

and categories for the expenses. For this assignment, the students were required to have both categorical and continuous variables in the survey questionnaire, as well as a brief description of sampling or their plans in collecting the data (see Appendix C for the handout). Below is an excerpt of her questionnaire.

> 1a. How many times do you attend concerts annually?
> A. 0-2
> B. 3-5
> C. 6-8
> D. 9 or more
>
> 1b. On average, how much do you think you spend on the concert? (expenses include tickets, travel, food, etc.)
> A. $0-$75.00
> B. $76.00-$150.00
> D. $151.00-$250
> D. $251.00 and more
>
> 2a. During baseball season, how many games do you attend (minor or major)?
> A. 0-5
> B. 6-11
> C. 12-17
> D. 18 or more
>
> 2b. On average, how much do you think you spend during the baseball game? (expenses include tickets, travel, food, etc.) A. $0-$20.00 B. $21.00-$30.00 C. $31.00-$40.00 D. $41.00 and more

It is possible that Hannah forgot to have continuous variables, or that it did not occur to her to leave these questions blank for the respondents to write the amounts. In addition, her demographic questions also had categories, such as age groupings: 18-21, 22-24, 25-27, 28-30, 30+.

Although Hannah lacked continuous variables in her survey questionnaire on assignment 2, she was able to edit it before the actual data collection. In particular, she

was able to ask about age as a continuous variable instead of having the categories. Below is our conversation about her experience on writing the survey questionnaire:

Interviewer: What can you say about the second homework? What was your experience in doing this one?—in developing the questions.
Hannah: Umm... my only challenge was... how to do the (a), (b), (c)—'cause I wasn't sure
Interviewer: ... oh the choices?
Hannah: Yeah... I wasn't sure... what the gap should be. But I figured, through my experience too—how many I went and how much I spent.
Interviewer: Uh huh... and I think I also suggested that you might wanna use some continuous variables.... so I think you did that here...
Hannah: Yeah, I changed that in my...
Interviewer: right here in the age?
Hannah: Yeah, instead of this, I just put age "blank."
Interviewer: Oh ok. So that helped you in creating this one... or you used that data...
Hannah: Yeah, knowing exactly how many were 21 years old…

This conversation revealed that Hannah was able to incorporate some of the feedback, which prompted her to make some changes to her survey question. The variable age had been a categorical variable, and she changed it to a continuous variable. Although it would have been more interesting if she had collected the prices or costs as continuous variables. Still, this shows that she put in the time and effort to improve her survey instrument, and that she was attending to the feedback she received as a way of informing her decisions to make changes in her survey.

Interestingly, Hannah had some challenges with writing the categories. She was able to use her previous knowledge and personal experience, particularly in developing the categories. However, it is possible that Hannah did not realize that there were two ways of phrasing the survey question: one that involved categories and another that had continuous variables. We can infer that Hannah assumed that these survey questions should all be multiple choice questions, and so she created the choices or categories.

Because of her limited background in writing survey questionnaires and in taking surveys, it made some sense to her to use her own experience as a starting point in making the choices.

When I asked her if she spent a lot of time in writing the survey questionnaire, she said, "*Not a whole lot because I learned from my RPTA major the kind of questions you need to ask*." For example, the third question on her survey specified both major- and minor-league baseball games; this distinction is important because responders should eliminate children's baseball games in the count, and include minor-league games in the count. She also explained that it was important for her to be clear about how she was defining expenses, which included the tickets, travel, and food, as indicated in her survey questionnaire. She pointed this out in the interview: "*I needed to be specific with the expense... 'cause I didn't want them thinking it's just tickets or whatever—I wanted it to be like the whole expense*." Thus, the quality of the survey questions showed that Hannah carefully constructed these in a thoughtful way based on her own personal experience and from the information that she obtained from her RPTA course.

Recall that Hannah did not provide a rationale in the first homework assignment, and so she felt the need to write a rationale or goal in this second homework assignment. Here is what Hannah wrote in the second assignment as her research goal: "This will also help me determine how much they spend on these activities. I want to make a connection with my own hypothesis: if the economy is affecting their spending, then the amount of concerts and baseball games attended are very low." The first sentence is in line with what she has on her survey questionnaire: expenses at concerts and baseball games. The second sentence shows her true goal of connecting the survey questions to her

hypothesis: “if the economy is affecting their spending, then the amount of concerts and baseball games attended are very low.” Because the second assignment builds on the first, she felt the need to explain her research goal. However, this implication is ambitious because she did not include any survey questions about the economy or spending habits. Hannah could have asked specific questions such as a comparison of spending or attendance at concerts/baseball games before and after the economic crisis, or an opinion question on views about the economy that could be answered on a Likert scale.

In addition to the survey questionnaire, the students were also required to write a description of their plan on the data collection. Hannah wrote that she originally planned on randomly sampling 50 or more students at the university’s cafeteria and lounge. She wrote:

> I will conduct a random sampling survey around campus. However, most of the survey will be coming from my work (in the Union) and in my major (RPTA). If I need more sample, I might survey the class. I will pass out the survey and collect data for about 2 to 3 weeks or until I have collected about 50 or more surveys.

In reality, she was only able to survey 30 students and she collected her data from two RPTA courses that she was taking. Thus, she made some changes from her proposal to the actual data collection. It is possible that Hannah realized the complexity of conducting a random sample, and so she opted for the convenient way of obtaining the data by asking the other students in her classes to fill out the survey.

Overall, she found the process of collecting data and making sense of it useful for her work with the local baseball team, Windstar. She said “*I’d probably do something similar, like gathering information and stuff from other leagues, and report back*.” Throughout the interview, Hannah articulated the usefulness of going through the process

of the statistical investigation. She explained further: "*I didn't just do this because it was homework. I kinda took time to do it. So it was helpful.*" Hannah was motivated to complete the statistical investigation because she valued the usefulness of the task and how it could prepare her for her future career. Furthermore, she did not view this as another math homework that needed to be worked on; rather, she put in the time and effort to complete it.

4.2.3 Analyzing the Data and Interpreting the Results (HW#3)

Visual Displays of Data and Interpretation. Hannah's third homework assignment included a table on age frequency and relative frequency, and three graphs. One of the graphs was a line graph of the relative frequency by age, which was very similar to the example that was presented in the class lecture. The other two graphs were bar graphs of the expenses at concerts and baseball games, based on the categories in her survey. The table and graphs that she included in the report can be found below (Figure 4.1).

Hannah was able to produce the graphs in Excel and interpret the graphs correctly. For example, on discussing the age frequency, here is the interpretation that she wrote on her third installment of the project:

> Since most of RPTA students surveyed were upper division, the distributions of ages were between 21 and 25 years of age (see Table 1 and Figure 1). The central tendency measurements of the results showed that 23 years old was the average of age and 22 years old was the mode from the results. Table 1 and Figure 1 shows that 22 years old has the highest relative frequency base on the data.

Additionally, on the interpretation of the first bar graph on concert expenses, she wrote: "25 students out of 30 surveyed spent less than $70.00 on concert expenses (expenses includes ticket, gas, food, souvenirs, etc.)." Similarly, she wrote the following

interpretation of the last bar graph on baseball expenses: “Figure 3 shows the relationship between students and the amount spent. The results showed that students spent less than $20.00 on expenses although there is a good amount of students who spent between $31.00 and $40.00.” These are good examples of Hannah’s statistical thinking and reasoning because she was able to make sense of the data based on the context of her study. However, these graphs are uni-dimensional and that she presented one variable at a time. Her discussion of the age data showed that she could use statistics to describe measures of central tendency.

TABLE 1: AGE FREQUENCY

Age	Frequency	Relative frequency
21	5	16.7%
22	9	30.0%
23	6	20.0%
24	6	20.0%
25	4	13.3%

FIGURE 1: RELATIVE FREQUENCY

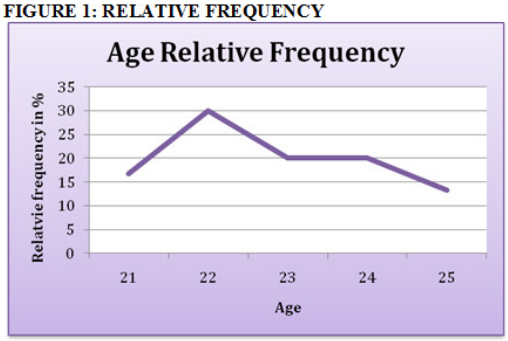


FIGURE 2: ACTIVITY EXPENSES

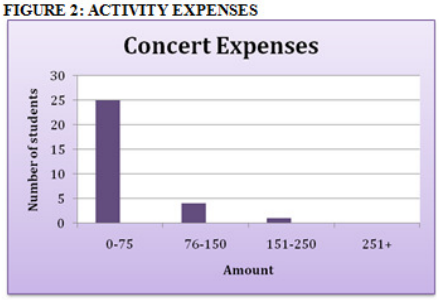


FIGURE 3: ACTIVITY EXPENSES

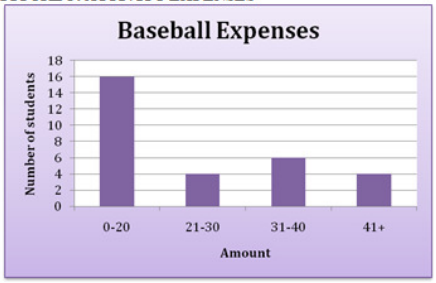


Figure 4.1: Hannah’s visual displays of the data

During the interview, Hannah said that she was more interested in the expenses or cost of going to concerts and baseball games than the age or attendance variables. She said:

> *Hannah: I... let’s see... I wasn’t surprised about the age frequency because we’re all similar in age. But maybe the expenses was more surprising to me. They didn’t spend a lot, as you can tell.*
> *Interviewer: Yeah, nobody really wanted to spend over $250.*

> *Hannah: And I think the same with baseball too, they didn't spend too much because... if you think about, if you go to the Windstar game they're very like inexpensive.... so it's kind of the same thing.... they don't really... spend a whole lot either.*

This shows that Hannah was trying to make sense of her data, and relate it to her work at the local baseball team in addition to her personal experience. Because Windstar is considered a minor-league baseball team, tickets are available for as low as $8 per person, and some people can even get free tickets from local sponsors (e.g., gyms, radio stations, etc.). This is why Hannah came up with $0-$20 as her first choice or category for the baseball expenses.

Attendance at Concerts and Baseball Games. Hannah was also interested in the number of people who attend concerts and baseball games. In the results section of her report, she wrote the following excerpt of the analysis and interpretation of the results:

> There is an average of 1.43 concerts attended by students annually. Baseball games are easier to attend than concerts. Moreover, more males attend baseball games than females; however, most of the survey was distributed to a particular sample population: Recreation, Parks, and Tourism Administration (RPTA) students. In most of my RPTA classes, there are more females than males, so the results showed more females (18 females and 12 males). It showed some biases to the results because I hypothesized that more males would attend more baseball games. An average of 10.67 baseball games were attended annually.

Notice that the first and last sentences of the above excerpt (underlined for emphasis) have the average number of concerts and baseball games attended per student: 1.43 and 10.67, respectively. These two sentences seemed inconsistent with the survey questionnaire that she proposed, because the results that she wrote on this assignment gave the impression that Hannah collected data on continuous variables. Recall that she proposed the following survey question: "How many times do you attend concerts annually? A. 0-2; B. 3-5; C. 6-8; D. 9 or more," which involves categorical variables. It

would have been better if she had shown the frequency or the distribution of the grouped data, followed by the computations of the mean. Based on her categories, she would have to multiply the frequencies to the midpoint of the groups 0-2, 3-5, 6-8; calculate the total product; and then divide the total product to the sample size, that is:

$$\bar{x} = \frac{\Sigma f \cdot x}{\Sigma f}$$

It is also possible that she collected the data without the categories, but again it is unclear because we do not have her final survey questionnaire.

In the previous excerpt of Hannah's work, she also hypothesized that "more males attend baseball games than females" but later explained that her results are different from her assumption, or a contradiction. Note that she used the word "biases" when she actually meant contradiction. Hannah's hypothesis is a good way of looking at the data because it involves comparing the attendance in baseball games from two groups: males and females. Her written work appears to suggest that Hannah compared the attendance by gender; rather, her comparison was on the number of male and female participants: 12 and 18, respectively. Hannah attempted to confirm her hypothesis by comparing two groups, but failed to compare the average attendance by gender.

Hannah's Conclusion. Hannah separated the visual displays of the data from the text or explanation, which made it difficult for her to connect the results of her data and the interpretation, and so her conclusion was not as robust as it might have been. For example, she wrote in the first paragraph of her conclusion the following:

> In my hypothesis, I concluded that students would attend less concerts and baseball games and spend less because of the economy. Base on the

> results of my data, it was significant in both concerts and baseball games, but more significantly in concerts.

It appears that Hannah made two different comparisons in these two sentences. One comparison was about the attendance at entertainment events (concerts and baseball games) before and after the economic crisis (in years 2009-2010). Recall that she did not include any results about this particular economic claim, even if she had included a question about the economy in her final survey questionnaire.

The second comparison was about the expenses at entertainment events (concerts and baseball games) in order to arrive at the conclusion "more significantly in concerts." Recall that the graphs and her survey questionnaire had categories and that the bar graphs are not the same. The use of the word significant is also interesting because it is describing the difference in expenses between concerts and baseball. Note that this class only had descriptive statistics and did not include inferential statistics, which means that Hannah is using the word "significant" merely as a description of a big change.

In another section of her paper, Hannah appeared to have established her assumption about the connection between her data and the economy, and how students are attending and spending less money on these entertainment events. She wrote: "In this economy, students are spending less on their leisure activities. Although concerts and baseball are not part of a 'getaway vacation' (for example, a vacation to Hawaii), it is still a significant decrease in attendance." Hannah attributed her results to the economy; however, she does not realize that the economy is another variable. Her conclusion would have been stronger if she had data in her survey about the economy, or perhaps a comparison of spending habits before and after the economic crisis.

Lastly, it is unclear whether Hannah is forming the wrong conclusion or not because she did not include the final survey questionnaire that she used in collecting the data. The last sentence that she wrote on the third assignment shows that there is a possibility that Hannah added another question on how the economy is affecting the spending habits. Here is what she wrote: "In conclusion, the results supported my hypothesis because data showed that most students spent significantly less with the economy (students were ask if the economy affected their way of recreating, and most said yes)." The statement in the parenthesis shows that Hannah asked a question about the economy that was not part of her original survey questionnaire. However, she did not explain further the number of students who said "yes" or show the percentage. Thus, it is unclear if this is truly a valid statement or not. Did her data truly confirm her hypothesis or was she focusing on the information that is in line with her beliefs about the economy and entertainment? This is an example of confirmation bias because the way that she arrived at her conclusion is based on the hypothesis that she was not able to verify. During the interview, she said: "*I used to go to a lot of concerts, but not anymore. Baseball games, I still go a lot… Yeah, I do go on my day off, I watch baseball...*" which shows that Hannah was truly passionate about watching baseball games. However, it is possible that her prior knowledge about baseball attendance and personal experience clouded her judgment.

Biases and Limitations. In addition to the analysis and interpretation of the results, the students were also required to write some of the possible biases and limitations of their data. Hannah acknowledged the limitations of her survey because she collected her data from her RPTA classes. Because she was more familiar with the students in those

classes, she probably knew that these students go to baseball games and concerts. Here is what Hannah wrote on the limitation of her data:

> The survey was limited to only RPTA students with an exception of 1 student who is a minor. This created a limitation to the data because as mentioned before, most RPTA students attend baseball games and attend at least 1 concert; thus giving data more positive results on the baseball data.

This illustrates that Hannah was aware of possible selection bias because she only sampled her two RPTA courses. However, Hannah did not articulate that her sample might not be representative of the whole population of RPTA students.

Hannah was also aware that most RPTA students are interested in sports, and so she was already expecting to see that more students will attend baseball games than concerts, which could be a confirmation bias on her part. She wrote:

> There was possible biases base on the method of my survey collection. Since most of us "recreate," there is a possible chance that the attendance would be higher, however it clearly shows that the students on average spent less amount of time attending concerts than baseball. Most RPTA students are sports fanatic, so it is not a surprised that the results revealed more students attend baseball games.

It appears that Hannah started to explain the biases from her method of data collection, but proceeded to explain the results. It is possible that Hannah interpreted the word "biases" differently from "researcher bias." Recall that in an earlier example of her writing, she wrote the word biases, but she may have actually meant contradiction.

Logical Argument. Because this third assignment built on the second assignment, it appears that Hannah was showing some consistency in her conclusion. Recall that Hannah wrote the following in her second assignment: "I want to make a connection with my own hypothesis: if the economy is affecting their spending, then the amount of

concerts and baseball games attended are very low." This is a fairly sophisticated argument to make, and it is possible that Hannah did not even realize that this was not easy to establish or prove based on the data that she collected.

Furthermore, it is unclear if Hannah was implying a causal relationship in her "if-then" statement of the hypothesis. Her antecedent was: "*the economy is affecting their spending*" and her consequent was "*the amount of concerts and baseball games attended are very low*." Based on the data, she saw the consequent, and thus concluded that the antecedent was true, which is a converse error in logic (switching the order of the antecedent and consequent). Another way that Hannah could have proven her hypothesis is through modus ponens: "if p implies q, and p is true, then q must be true." That is, Hannah could have shown that her antecedent, "*the economy is affecting their spending*," was true, and then show that the consequent is also true. Equivalently, she could have also used the modus tollens form of argument: "if p implies q, and q is false, then p must be false." However, the lack of support for either the antecedent or consequent makes Hannah's conclusion vague.

In summary, there were both positive and negative things that Hannah did on her statistical investigation. Hannah treated both expenses and attendance at concerts and baseball games independently and interpreted them separately. This is a good way to make sense of the data because these are two different variables: expenses and attendance. Also, her categories are different in the two entertainment events: concerts and baseball games. On the negative side of things, Hannah was not successful in the following attempts: a gender comparison in the average attendance at concerts and baseball games, and connecting her results to the economy.

Although Hannah was able to adequately analyze the data, produce the visual displays of the data, and interpret the graphs, there are still major errors in her interpretation of the results, which shows that this phase of the statistical investigation proved to be challenging for her. Hannah mentioned that she did a similar project in her other course, which gave her an idea of how to do the data analysis. She said: "*In one of my RPTA class, we did something similar like this, where we would gather data and do like the graphs and stuff. It was fun doing that, I had fun. It gave me practice too 'cause I'm kinda like weak in Excel. [laughs] So it took me a while to figure out like how to do this stuff like this."* She explained that the project that she did in the course for her major was about managing a fictional Little League baseball team and they had to report cost estimates. Thus, it was more related to business, and different from the survey that she did in this math class. The classes that she took for her major informed her of the appropriate questions to ask on her survey, and the project also helped her in reinforcing the data analytic skills that she learned in her other classes. Overall, this project can be considered a low cost for her because her prior knowledge gave her the background or foundation in completing the project. But that very same prior knowledge could be the source of her confirmation bias and errors in the interpretation of the results.

4.2.4 Final Project & Reflection on the process (HW#4)

Hannah's last assignment included a brief introduction, a description of how she collected the data, and a summary of her results along with a brief reflection. She omitted the graphs and the survey questionnaire from the previous assignments. It is possible that her interpretation of the assignment (see Appendix E for the handout) only included the

major parts of the paper as outlined in the handout (introduction, methods, summary of the results, and reflection). She wrote the following as her introductory paragraph:

> My project relates to me personally because I grew up watching baseball and I am very passionate about music and concerts. Personally, I want to know how many of my peers from my major watch baseball games and attend concerts on a yearly basis. In addition, I also asked how much they spend on expenses to go to these events. I have hypothesized that the number of attendance for both recreational activities will be low and the amount they spend will also be low because of the economy.

Again, Hannah wrote that she is very passionate about baseball and concerts. This was a project that is very personal to her, and she was genuinely interested in this topic. Notice that the last sentence is about her hypothesis and that she attributed the results to the economy.

The last paragraph shows her reflection on the whole process, and again how it related to her personal interest. Again, her positive tone reflects her passion for baseball and how she personalized this project.

> This project was interesting because it allowed me to be creative and follow something that I'm really passionate about. I wanted to create something that I was able to relate to and something that is personal to me. I learned that women are starting to take part in baseball activities. They have something to look at (baseball players), and they can also enjoy hanging out at the ballpark. I got my best friend to really like baseball and now she is hooked, and it's amazing to see how much she's really paid attention to her team. She is now dedicated and passionate about the team. I know from personal experience that a lot of my friends hardly go to concerts, so it was interesting to see that there were still a reasonable average of concert attended.

The first two sentences show that being creative was an important motivating factor for her, along with her passion for baseball. She even described how her passion for baseball influenced her best friend.

The students were also required to discuss some of the changes that they might do to improve their study. In particular, I asked the students to explain how their results might change or remain the same if they had a larger sample or if they collected the data at another site. Below is what Hannah wrote on possible changes to her project.

> The one thing I would change about my project is the sample size and sampling more RPTA classes. I know I could have gotten more responses from males if I were to sample other RPTA classes, but because of time restriction, I was unable to gather more data. Moreover, I would also have surveyed the sooner I created my survey, but I didn't, so that created limitations for my project. I know that this project could have improved if the sample size was larger. I realized now that the sample size for this project was significant in many ways. The sample size can be the factor that be changed for improvement in further studies.

In this written reflection, Hannah realized that her sample size of 30 from the two RPTA classes might not be representative of her population of interest (all RPTA students). She also realized that she should have collected her survey data sooner than what actually happened.

During the interview, Hannah talked about the usefulness of the project in preparing her for her future career: "'*Cause I wanted to learn how to actually do the Excel, [laughs] and do my questions and write the results and stuff. 'Cause I knew that I would have to do something like this in the future, so I kinda had to take my time in doing it*." This shows that Hannah was motivated to learn more about statistics and data analysis because she realized the usefulness of the task beyond the scope of the class. Hannah could see herself doing something like this in her future career. Also, she was motivated to do well in the project because of her grade and in improving the scores that she got on the exams.

When it comes to grades, Hannah said that she only wanted to get a B, and she was worried about her grade because she was averaging around 75 or C. Below is our conversation about her grade:

> *Interviewer: Ok, were you worried about it [grade]? About your standing in class?*
> *Hannah: Yeah. I only had one— well, my test scores were average like 71, 75... I only had one bad test score and the rest were like 70s or 80s. So that kinda helped me out like be a little confident, but at the same time, I still wasn't sure I was gonna do well on the final 'cause it was cumulative final, and it was scary for me. So yeah.*
> *Interviewer: So what grade were you aiming for in this class?*
> *Hannah: Oh B, and I got a B. So its good. 'Cause I always get C's in math, so I was hoping for a B.*

Furthermore, Hannah was relying on the project to help her with attaining her grade (B). She said: *"Knowing that I have really bad —not bad test scores—but I knew I wasn't... I don't do well with math tests... I knew that if I don't do so good on those, I have these points to kinda help me out. And I like how your class had a lot of points distribution and homework and stuff. That made it easier for me to get a little confident about my grade."* She wanted to get a good grade in class, and not just pass it with the minimum amount of points, which is also evident in what she said in the usefulness of the project. In the end, she was successful in attaining the grade that she wanted, a B.

4.3 Academic Effort and Learning Opportunity

Academic Effort. Hannah was able to successfully complete the statistical investigation, and she showed substantial effort in her work. She proposed five research topics in her first assignment, which was the maximum requirement. She was able to incorporate the feedback, learn from her mistakes (e.g., missing continuous variable), and edit her final survey questionnaire. Hannah's chosen topic was important and interesting

to her, and she valued the usefulness of the task. Her prior knowledge also contributed to her success, and her work showed that she transferred some of her prior knowledge to this project. Below is our conversation about the effort that she put in the project:

> *Interviewer: OK. How much time did you spend on that [HW#3 - analysis]?*
> *Hannah: Umm... the graphs, it took me awhile... maybe like 20-30 minutes. I had to go back to my project that I did for my major... to see how to input it in Excel.*
> *Interviewer: Oh I see... Did you have to do some of it by hand? Like tallying…*
> *Hannah: Oh, yeah I did some... I had like a scratch [paper]... I went back to the result that they marked and I tallied it… Yeah... and when I got all of them [survey results] I just wrote down 20 males, or whatever how many females.*

This shows that Hannah put in the time and effort in making this a successful statistical investigation. Hannah described that she had to review her work from her previous RPTA course, and then count the number of responses for the variables that she had on the survey, which she put in Excel to produce the graphs. Below is our conversation about the time that it took her to complete the third and fourth phases of the statistical investigation.

> *Interviewer: So did you think that the amount of effort that you put in here was worthwhile?*
> *Hannah: Uh huh.. I didn't have a lot of other homework, so I got to spend on a day with just focusing on this project... so that was just this... I didn't have a lot to do at that time.*
> *Interviewer: Oh that's good. And then for homework 4, was it pretty much the same thing too?*
> *Hannah: The last one, I spent the whole day too doing that.*

Because Hannah did not have a lot of homework from her other classes, she was able to put in a whole day on each of the last two phases of the project. She was able to concentrate on this class and put in the time to work on completing the statistical investigation.

Learning Opportunities. There were many instances of Hannah's learning opportunities throughout the four phases of the statistical investigation. In the first assignment, she proposed topics and survey questions. The second assignment showed a draft of her survey questionnaire that looked at attendance and expenses at entertainment events: concerts and baseball games. The third assignment revealed that she was able to show the various ways of visually representing the data through graphs, and she was successful in doing the analysis and interpretation of the results. However, there are areas of improvement, especially in developing her argument based on the data that she has.

Using Mooney's framework (Mooney, 2002; Mooney, Langrall, Hofbauer & Johnson, 2001) of characterizing middle school students' statistical thinking, we can identify instances where Hannah was reading between the data and beyond the data. We can see that Hannah made only single comparisons within her visual displays of the data. Recall the following statements that she wrote about the expenses at concerts and baseball games: "25 students out of 30 surveyed spent less than $70.00 on concert expenses," and "students spent less than $20.00 on expenses although there is a good amount of students who spent between $31.00 and $40.00." These statements show that Hannah's level of statistical thinking is transitional in interpreting the visual displays of the data based on Mooney's framework of reading between the data. Since her categories for the expenses were different for concerts and baseball games, it does not make sense to make global comparisons between the data sets.

Hannah also attempted to "read beyond the data" by attributing her results of the low attendance and expenses to the economy. However, she did not have enough information to establish her claim because she did not include any questions about the

economy. Mooney calls this an idiosyncratic level of reading beyond the data because Hannah made an inference that is not based on the data.

Throughout the interview, she revealed her interest in the project and in learning more about the process of collecting data, analyzing the results, and forming conclusions. She was able to appreciate and learn the process of statistical investigation. She also discussed her previous experience in her RPTA class, which shows transfer of learning to this project. During the interview, I asked her to describe how she felt during the first few weeks of the semester when I announced that the students were going to have a project in class. She said:

> *Um, well, when I found out that there was a project in this class, it was kinda weird... like a project in a math class. I was talking to my co-worker, and she said, "That's weird to have a project in a math class," but as I did homework 1 and 2, I felt kind of—"oh, this is good"—you know, it's fun. It's something that I get to choose. And I ended up liking it. At first I felt weird that we had a project. But I wasn't totally against it, and I enjoyed it.*

It was interesting to learn that Hannah "felt weird" about having a project in a math class, but something changed in the middle of the semester as she became more engaged in the statistical investigation. This shows that the statistical investigation was a task that fostered Hannah's motivation and statistical reasoning. She also appreciated the whole process of the statistical investigation and how the structure helped her in developing hr project. She said:

> *Hannah: Uh, besides learning more about Excel... just putting it all together... and working step-by-step, that helps, how you did it... like one project or homework at a time. Not just one big project at the end. How you had given us time to... for you to like go over it and check it. That was helpful because you learn from it too.*
> *Interviewer: So giving you that structure helped?*
> *Hannah: Yeah, I like how it was structured 'cause you gave us your input, and then it kind of... I went back and kind of went with your input.*

Interviewer: So the feedback....
Hannah: The feedback helped, yeah.

It appears that having the different phases of the statistical investigation allowed Hannah to build on to the previous parts and use the feedback to improve her work. She also said in another part of the interview that the project changed her way of thinking about math and statistics as subjects that are just purely computations; rather, math and statistics can be applied into a project that she is interested in. Below is our conversation:

Interviewer: So did this project change the way you used to think about math and statistics?
Hannah: Uh, yeah... when I did this, I had to look back to my notes and like how to do it. I wanted to do the uh... some—that one equation but I couldn't figure it out. [long pause]
Interviewer: Standard deviation?
Hannah: Yeah that one, but I couldn't figure it out, so I gave up. It took me awhile to figure it out. But yeah it definitely made me use what I learned in class, and put it into this project.

Hannah pointed out that she wanted to use the formula for the standard deviation but she was not successful at it. However, she was able to use the other concepts that she learned in class, and apply these concepts to the statistical investigation. Below is her overall impression of the project and her opinion:

Hannah: Yeah, I think it's really good. And for me, it helps with my grade. So hopefully they have that mindset—"oh, it will help with my grade." But then some people might be like—"uh, just another thing to do." But I really enjoyed it. So, I would like it for you to have to do this again. 'Cause it's something different... like you never see a math class doing other than just class work and tests.
Interviewer: Right, or problems out of the book.
Hannah: Yeah.
Interviewer: Ok. Do you have any suggestions or comments for future students about doing this?
Hannah: No, I like how you did it, how it's structured... not just one big project at the end. I like how it's split up.

She also mentioned that in her other classes, some professors would not give feedback, or that they would just require one big project at the end without much help or scaffolding. And so Hannah appreciated the phases of the statistical investigation because it gave her the chance to make further edits or changes to improve her work. She also liked that it helped her with her grade.

4.4 Lessons Learned from Hannah's Work

What can we learn from Hannah's statistical investigation? Hannah's statistical investigation was successful at her developmental level, and she was able to show statistical reasoning and literacy. She was able to narrow down her two main topics based on the five topics that she proposed. Still, there are improvements in the writing prompt for the first assignment that can be implemented, particularly in directing students to write specific research questions instead of allowing them to explore vague topics. Bean (2001) suggests that in order to encourage student engagement in research papers, instructors should begin by having the students learn how to ask research questions. He said, "Faculty, therefore, must not only motivate students to become question askers but also guide them toward asking discipline-appropriate questions that are interesting, significant, and pursuable at the undergraduate level" (p. 202). Hannah seemed to be a motivated but more guidance on how to write researchable questions might have amplified her learning. Thus, the statistical investigation is a way that we can motivate students to ask research questions and pursue these projects with passion while fostering their statistical reasoning and thinking. And Hannah demonstrated this motivation and statistical thinking in her project.

Hannah was also successful at developing her survey questionnaire by including questions on the attendance and expenses at concerts and baseball games. However, casting these questions (1a, 1b, 2a, 2b) to yield continuous variables would have enabled her to do more nuanced statistical analysis. It would have been easier if she had just collected ungrouped data, and then later created the groupings based on the raw data, similar to the exercises in the book when the topic of histograms and grouped data are introduced. Having to construct the "gaps" or "bins" in the categories without any data made this assignment more difficult for her. It is possible that there might be some prior assumptions about having to circle choices in survey questionnaires that made her think that creating the categories was required. More attention to the advantages of categorical versus continuous variables might have helped Hannah to make better decisions in this regard.

The good thing about providing categories in a survey questionnaire is that it can facilitate the data analysis because the data are already grouped together. However, it can also be a hindrance, especially if there is no variability in the data (i.e., if all respondents picked the same category), or if the categories themselves are too wide. But the more serious error in survey development is the lack of validity in the questions, especially if the survey questions do not answer the research objectives.

It appears that the lack of clarity in Hannah's research goal affected the validity of the survey questionnaire. In other words, Hannah's survey questionnaire might not be valid in the context of her research goal because of the disconnect between the instrument and the objective. Recall that she wanted to connect her results to the economy, but she

failed to include questions on her survey that tapped into spending habits at entertainment events (concerts and baseball games) before and after the economic crisis.

As for the data collection, Hannah surveyed the student in two of her RPTA courses. Convenience sampling is a typical scenario because most students will try to find a way of quickly getting the data, which can lead to a sample that is not representative of the population. Nonetheless, if students are to successfully complete the process of statistical investigation in one semester, then having a convenience sample is a good compromise.

On the upside, Hannah was able to analyze her data, show the graphs, and interpret the results successfully. She was able to use Excel by building onto her prior knowledge. Hannah struggled with applying some of the concepts, such as the standard deviation, but she was able to use the other concepts and produced a good final report. In particular, she focused on the categorical variables by showing the frequencies in the bar graphs and table. It is possible that she was also able to use continuous variables in computing the average number of concerts and baseball games that the RPTA students attend in a year.

Hannah was very motivated about her topic, which shows in her effort in the work that she produced, as evidenced by the statistical investigation. She was truly interested and enjoyed working on the project. In the end, we can see that Hannah's skills in analyzing data statistical reasoning and her motivation were enhanced and supported by the statistical investigation. She applied several skills but it is not clear if her statistical reasoning improved because she wanted to relate her results to the economic crisis but this is beyond the scope of her data.

To summarize this chapter, Hannah's case helped in understanding how the statistical investigation could foster motivation and a better appreciation of statistics. This investigation was for a mathematical reasoning class where students learned about descriptive statistics only, with inferential statistics being beyond the scope of the class. In the context of this class, Hannah's work demonstrated adequate analysis even though she presented very simple graphs and she had some problems with reading beyond the data. Nonetheless, Hannah's case showed how she capitalized on her passion for the topic to sustain her effort throughout the four phases of the investigation. It also shows that when students design their own survey questions, the data they get from the survey can be difficult to analyze. Despite this difficulty Hannah persisted with her project which is a testament to how highly she valued her investigation.

Chapter 5: Content Analysis of the Overall Data

In this chapter, I focus on the content analysis of the statistical investigations from 60 students in class, organized by the four phases of the project. First, I report on the important frequencies and percentages of the codes or categories that I identified from the projects. For example, I describe how I coded the kinds of questions, research methods, types of variables used (categorical or continuous variables), and quality of the analysis from the statistical investigation. In the next subsection, I report on how I analyzed these codes quantitatively; in particular, I describe how I tested for the association between the nature of the data and the quality of the analysis in the statistical investigations.

5.1 Formulating Questions & Data Collection

Recall that the four phases of the statistical investigation or the assignments are as follows: (1) *formulating a question;* (2) *collecting data;* (3) *analyzing the data and interpreting the results;* and (4) *reflection on the process*. Below is the distribution of the number of phases completed by the 73 students enrolled in the class.

Table 5.1: Completion of the 4 Phases of the Statistical Investigation (N = 73)

Completed	Frequency	Percentage
All 4 phases	46	63.01
3 phases	14[a]	19.18
2 phases	7	9.59
1 phase	3[b]	4.11
None	3	4.11

[a]1 missed HW1; 9 missed HW3; 4 missed HW4.
[b]1 student dropped the class.

The majority of the students, 63.01%, completed all four phases of the statistical investigation, while only 4.11% of them (three students) did not do any of the four phases of the statistical investigation. For those who completed only three out of four phases of

the statistical investigation, only one student missed the first homework assignment but completed the rest; nine of them missed the third assignment on data analysis but included it in the final assignment; and four of them missed the final assignment, which adds up to 14 students (or 19.18%). The final sample size for this study came down to 60 students who completed at least three phases of the statistical investigation. Thus, I excluded the following: the three students who did not participate in any of the phases, and the 10 students who turned in only one or two installments of the statistical investigation. The majority of these 10 students only completed the first two parts of the project (formulating questions and data collection), and their limited work does not show enough information to be included in the larger database. Only one student dropped the class, and she only turned in one of the four phases of the statistical investigation, thus excluding her from the sample as well.

5.1.1 Questioning the Question (HW #1)

The students were required to submit two to five research questions or topics for their statistical investigation, and provide a rationale (see Appendix B for the handout). With the exception of one student who did not submit the first homework assignment on formulating questions, the majority of the students submitted three research questions or topics (29 out of 59 students, or 49.15%), followed by 14 students (23.73%) who submitted only the minimum requirement of two questions or topics, while eight students (13.56%) and seven students (11.86%) submitted four and five research questions or topics, respectively. One of the students misunderstood the task and submitted six questions that were more suitable for an interview, because the overall theme of his questions was about selecting a major. This particular example will be explored further in

the case studies chapter. There were also two students who submitted three questions with an overall theme that were appropriate for the next assignment of writing a survey questionnaire.

It was of some interest to see the quality of the questions that the students posed. Based on an overall sample of 188 research questions or topics, I identified four major types or classifications that the students proposed. These are (1) frequency questions for categorical variables; (2) questions requiring descriptive statistics for continuous variables; (3) comparative questions; and (4) correlation, association, or relational questions. Some of the questions or topics had one or two codes or types because some students wrote sub-questions or combined two questions in one, resulting in 225 codes. Below is a table that shows the frequencies, percentages, and examples of research questions.

Table 5.2: Types of Research Questions

Types of Research Questions	**Frequency (%)**	**Examples**
(1) Frequency questions for categorical variables	119 (52.89)	"Are you a dance major or minor?"
(2) Questions requiring descriptive statistics for continuous variables	40 (17.78)	"How many hours per day/week do you spend doing homework and studying?"
(3) Comparative questions	28 (12.44)	"Do students who are active participants in collegiate sports do better in their classes than students who just attend the college for academic reasons?"
(4) Correlation, association, or relational questions	38 (16.89)	"Is there a strong correlation between a person's shoe size and his or her height?"

Instead of writing research questions, some students wrote their proposed topics or hypotheses. I identified 46 out of 188 questions that followed this style. For example, one of the students wrote:

> Political News IQ: Almost any look at what the average citizen knows about politics is bound to be discouraging. Americans tend to remember or identify trivial details about political leaders, focusing on personalities or simply latching onto the policies that the press plays up. Rather than being educated on important political issues. I would like to survey students on basic political knowledge and see how educated Americans are on current politics.

In this particular topic, the student was interested in counting the number of people with basic political knowledge or reporting the percentage of survey respondents who could answer correctly some of the basic ideas in politics. Also, the first sentence above shows that this particular student had a hypothesis about the lack of political knowledge that most people have. It is possible that some students are more comfortable with stating a topic or hypothesis, rather than posing a research question.

However, a more problematic research question for a statistical investigation is that of a qualitative research question. There were only 13 questions or topics out of 188 that were qualitative. For example, one of the students wrote: “With the popularity of the itunes website, will cds eventually be unnecessary products?” Although this question is interesting, the student could have posed it quantitatively by comparing the number of people who buy CDs versus those who download music.

5.1.2 Population of Interest & Final Topic (HW #2)

The majority of the students proposed questions or topics that were about the student population; for instance, one of the students wrote: “I would like to survey 50

students and ask them about what they are planning to do after graduation. For example, I would like to ask if they are thinking about going to grad school…" Other students were not interested in the student population, but rather a more general population or a specialized population. For example, one student was interested in studying the opinions of people in the military, while another student wanted to conduct a career-related survey of the employees of a particular company.

Interestingly, there were three students who proposed one or two questions that involved self-repeated measures, such as counting the number of jumping jacks one can make or keeping track of one's weight for a month with exercise. Below is an example of this proposed topic:

> I would like to keep track of the amount of water an athlete such as myself intakes and how I feel during my workout. I will try drinking different amounts of water and cataloging how much, how often and how I feel after I go to practice.

Although these self-repeated measures were proposed in the first phase of the statistical investigation, the students did not choose these for their final topic in the second phase of the project. Table 5.3 has the frequencies and percentages of the population of interest from the first two phases of the investigation. For the students' final topic, 85% of the students chose to concentrate on the student population for their project, while 15% of them did not survey the student population.

I also catalogued the research questions or topics that the students proposed for the first phase of the statistical investigation and the final topics that they chose. These topics or research questions spanned a wide variety of subject matter or themes, such as time allocation, health or food issues, career or job, entertainment, politics, and

environmental issues. Note that some of the topics or research questions had overlapping themes, which resulted in one to three codes per topic or research question. For example, Hannah proposed her topic on the attendance and expenses at the following entertainment events: concerts and baseball games, which was coded as entertainment, money allocation, and sports. Table 5.4 has the frequencies and percentages of the themes from the first two phases of the investigation. It was interesting to see that the majority of the students focused on academic-related themes, followed by food- or health-related issues and time allocation.

Table 5.3: Population of Interest in Homework #1 and #2

	Proposed (HW #1)		**Final Topic**	
	Frequency	%	Frequency	%
Student population	111	59.04	51	85.00
NOT a student population	72	38.30	9	15.00
Self-repeated measure	5	2.66	0	0.00
Total	188	100.00	60	100.00

The majority of the students, 81.67% (49 out of 60), chose their final topic based on the list of proposed research question or topics from the first homework assignment. Only 11 students (18.33%) decided to choose completely different topics from the previously proposed ones, which was partly based on feedback from their first assignment. One of these 11 students is a case study participant, Grace, and she initially proposed three topics, on news sources, digital music, and food. Here is an example on one of the initial topics or research questions: “I’d be interested in finding out how many students under the age of 25 actually read the newspaper. Will the newspaper survive as the generations go on?” For her second assignment, she proposed a different topic, relationships. She wrote:

> After reviewing homework 1, I decided to change my research question. My new question is: "Does being in a relationship affect CSUX students' grades in school?" I decided to choose this question because I currently have a boyfriend and my mother believes that my grades are decreasing since I am constantly with him. So, I am very interested to find out if student's grades are affected by the fact that they have a significant other or not.

Grace did not choose her initial topics because some of her questions were qualitative in nature. She thought about another research question and proposed it on the second phase of the project. This shows that some students can benefit from being given a second opportunity to rethink their proposed topics in order to move on to the second phase. Some students need this scaffolding structure in order to arrive at a good topic that will lead to a successful statistical investigation.

Table 5.4: Topics or Research Questions—Major Themes

	Proposed (HW #1)		**Final Topic**	
	Frequency	%	Frequency	%
Time allocation	22	7.10	9	8.50
Money allocation	16	5.20	6	5.70
Food or health	39	12.60	13	12.30
Sports or exercising	20	6.50	6	5.70
Career or job	24	7.70	7	6.60
Academic	60	19.40	29	27.40
Choosing or switching majors	13	4.20	5	4.70
Social or psychological study	6	1.90	5	4.70
Relationships or family	10	3.20	2	1.90
Entertainment	31	10.00	5	4.70
Pets	2	0.60	0	0.00
Clothing or fashion	2	0.60	0	0.00
Transportation or commuting	10	3.20	3	2.80
Politics or news	9	2.90	3	2.80
Background or physical characteristics	21	6.80	1	0.90
Technology use	13	4.20	4	3.80
Environmental issues	2	0.60	2	1.90
Working while in college	6	1.90	4	3.80
Moving to another area	4	1.30	2	1.90

5.1.3 Survey Instrument & Data Collection

In the second phase of the statistical investigation, the students were required to include their survey questionnaire that had both continuous and categorical variables. Only three students out of 60 (5%) did not turn in their survey questionnaire; rather, they only described how they were planning on collecting the data and discussed some of the variables that they were planning on collecting. Most of the students, 38.33% (23 out of 60), needed some minor revisions on their survey questionnaire, which included fixing spelling errors, editing categories that had overlaps, and specifying the unit of measurement for continuous variables.

There were 20 students (33.33%) that needed to do major revisions on their survey instrument because some of the questions were not appropriate or lacked validity. All 20 students only had categorical variables, and did not include any continuous variables in their survey questionnaire. There were only 14 students (23.33%) who had both continuous and categorical variables in their survey, and had questions that were appropriate or in line with their research questions.

The table below shows the different ways that the students collected their data. It appears that most students collected their data by sampling other students in a class, which is a form of convenience sampling. There were 14 students who reported that they randomly selected students to answer their survey, and they collected their data outdoors in the university near the cafeteria or library, which is also a form of convenience sampling. Only 11 students reported that they collected their sample online, while another 11 students said that they collected a random sample of participants. Although the

students did not actually do a true random sample, this is what they called their sampling technique, which I suspect is truly a convenience sampling done in various ways.

Table 5.5: Students' Data Collection Methodology (N = 60)

	Frequency	Percentage
Random sampling	11	18.33
Random sampling—outdoor	14	23.33
Convenience sampling—online	11	18.33
Convenience sampling—classroom (cluster)	24	40.00

All 60 students collected data with a sample size of at least 30, with a maximum of 189 participants. The mean reported sample size was 47.07 participants (SD = 24.49) and the median was 40 participants. It was interesting to see that 20% of the students (12 out of 60) met the minimum of 30 participants, while the rest obtained more. Only 5% (3 out of 60) had a sample size of 100 or more.

5.2. Data Analysis & Interpretation of Results (HW #3)

All students were required to include at least two forms of visual displays of data in the form of graphs or tables. All of them met this minimum requirement except for four students who did not turn in any visual displays of data; one of them was a case study participant, Quinn. Table 5.6 shows the different ways that the students presented their data.

Table 5.6: Students' Visual Displays of Data

	Frequency	Percentage
Bar or line graph	96	50.79
Pie chart	38	20.11
Scatter plot	11	5.82
Table of frequency	14	7.41
Table of descriptive statistics	18	9.52
Raw data in a table	12	6.35
Total Graphs or Visual Displays	189	100.00

The majority of the visual displays of data that the students presented consisted of bar or line graphs, at 50.79%, followed by a pie chart, at 20.11%. Both of these graphs showed the frequencies or counts for categorical data. Some of these visual displays of data showed the descriptive statistics, at 9.52%. It was surprising to see that nine students decided to include a table of the raw data that they had collected.

I also looked at the quality of the visual displays of data, and the majority of these graphs, 92.02%, were relevant visual displays of data, with only a few that had missing labels, such as missing percentages in pie charts. Table 5.7 shows the frequency and percentage of the quality of the visual displays of data. Since the students were required to show at least two visual displays of data, the quality of the tables or graphs was assessed holistically, rather than examining each graph out of context. For example, some students presented two pie charts (e.g., one for males, the other for females) with the same quality (i.e., relevance or accuracy), and so these were coded as one. Other students presented two different graphs from different variables that resulted in two separate codes. Thus, the total number of graphs that were assessed for quality resulted in a lower number than the previously identified total number of graphs or visual displays of data.

Table 5.7: Quality of Students' Visual Displays of Data

	Frequency	Percentage
Relevant with labels	127	77.91
Relevant without labels	23	14.11
Irrelevant	4	2.45
Inaccurate	9	5.52
Total	163	100.00

As mentioned above, the majority of the visual displays of data that the students presented in their report used bar graphs and pie charts, which involve using categorical

variables. There were 28 students out of 60 (46.67%) who used only categorical variables in the analysis, while a little over half of the students (32 students; 53.34%) used a combination of both categorical and continuous variables. By examining the quality of the analysis, I identified that 46.67% of the students (28 students) showed adequate analysis, which includes relevant visual displays of the data and accurate interpretation of the data and discussion of the results. Only a quarter of the students (15 students) had partially adequate analysis as evidenced by minor problems in the interpretation of the results or inaccuracies in calculating the descriptive statistics or displaying the data. For example, some of the students presented a scatterplot with an unknown label on one of the axes, while other students had errors in computing the mean and standard deviation. A little over a quarter of the students (17 students; 28.34%) had inadequate analysis and interpretation of the results. The contingency table below shows the quality of the analysis (or adequacy of the analysis) based on the nature of the data or the types of variables that the students chose to focus on—categorical or with continuous data.

Table 5.8: Quality of Analysis and Nature of the Data

	Categorical Data	Continuous & Categorical Data	Total
Adequate analysis	19	9	28
(%)	(31.67)	(15.00)	(46.67)
Partially adequate analysis	5	10	15
(%)	(8.33)	(16.67)	(25.00)
Inadequate analysis	4	13	17
(%)	(6.67)	(21.67)	(28.34)
Total	28	32	60
(%)	(46.67)	(53.34)	(100)

The chi-square test of independence of the table above shows that the quality of the analysis is associated with the nature of data, or there is a significant relationship

between the quality of the analysis and the nature of the data ($\chi^2 = 9.780$, $DF = 2$, $p = .008$). Although all students were required to have both categorical and continuous variables in their survey data, most students chose to focus on reporting categorical data and they were able to successfully analyze their data. It is possible that some students did not understand the difference between categorical and continuous variables, and that some students strategically chose to analyze categorical data because they might have perceived it as easier to do. At this course level, categorical data analysis only involved counting frequencies and reporting the percentages or relative frequencies.

The above results show that among those who focused on collecting and analyzing categorical variables only, 67.86% of these students were able to adequately analyze their data (19 out of 28). On the other hand, among those who focused on collecting and analyzing both types of variables showed that 76.47% of them were not successful in analyzing their data (13 out of 17). This means that the students who used only categorical variables appear to be more successful or more likely to analyze the data adequately, while a poorer quality of analysis was observed for those who used both variables.

The students who used both categorical and continuous variables seemed to have stumbled on providing irrelevant graphs or inaccurate interpretation of the data. For example, a copy of the scatter plot below is from a student named Camille who attempted to graph the number of hours of sleep and students' grade point average (GPA); Camille was not successful in establishing the relationship between the two variables because she seemed to have a different variable than the GPA on the x-axis. The paragraph below is Camille's interpretation of the graph, which also does not go well with the graph.

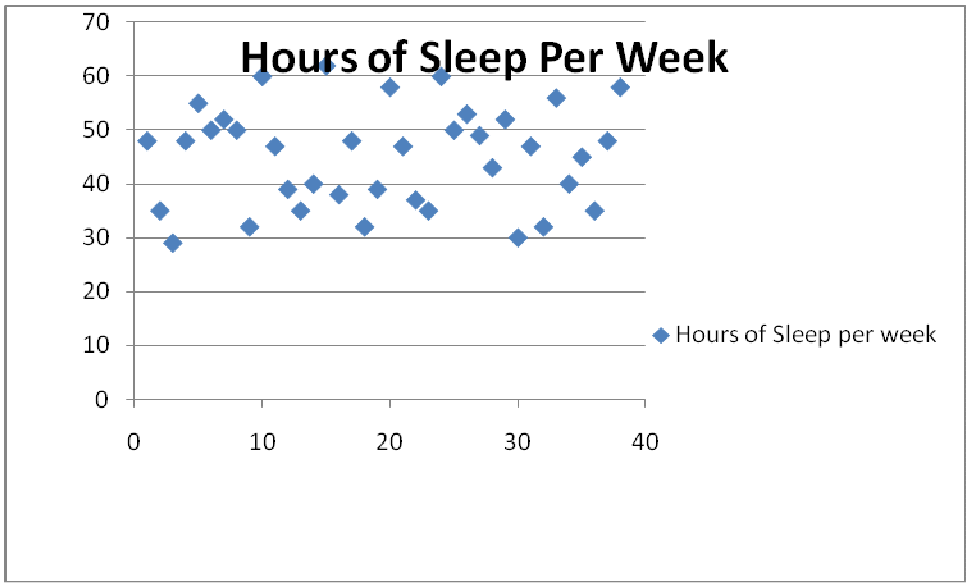


Figure 5.1: Example of a Student's Scatter Plot with Inadequate Analysis

> This graph shows that there are no particular outliers. The average amount slept per week is 45 hours, which gives an average of 6.4 hours slept per student at night. …If you look at this graph, there is a larger cluster of data located between 35 and 50 hours of sleep. This corresponds to how my data shows the largest amount of individuals have GPAs between 3.0 and 3.4 because I averaged 35 and 50 hours to get 42 hours per week which is an average of 6.1 hours of sleep per night. This is relatively close to 7 hours which is what I found was a good amount of rest to get per night; thus, these students have good grades

Camille's interpretation shows an attempt at making sense of the scatterplot by looking at the cluster of data points on the hours of sleep and linking it to the GPA. However, it is hard to determine what data she might have been using for the horizontal axis. It is possible that she assigned a number to each participant which was then used for the x-axis. In any case, her graph does not support analyzing bivariate data.

Below is another example of a student's inadequate analysis consisting of a graph of average GPA, gender, and whether or not the respondents drink caffeine (P42, page 6). The student, Don, wrote the following interpretation: "As you can see from the pie chart, the numbers look a lot more even, with the exception of the average female caffeine

drinker, who has the notably largest piece." Although Don recognized that the larger piece of the circle represented female caffeine users, he does not seem to understand that this means that more of his sample were members of this group. Clearly this pie chart was not a good choice because the student is mixing up the continuous variable (GPA) with two categorical variables (gender and caffeine drinkers). The continuous variable was not appropriate for this pie chart, and it would have been helpful if the student had reported on the number of respondents and percentage in each of the four categories, instead of the average GPA.

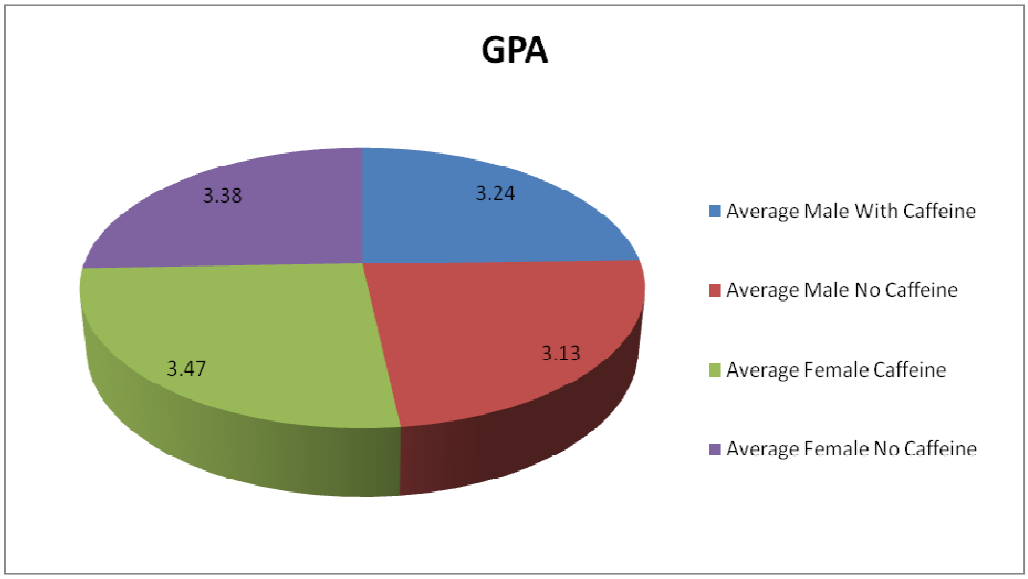


Figure 5.2: Example of a Student's Pie Chart with Inadequate Analysis

This particular student who presented the pie chart also used a bar graph as another way of presenting the above information (see Figure 5.3), which is a more appropriate visual display of the data than the pie chart above. The student reiterated the values on the bar graph, but did not attempt to interpret these values further. He wrote:

> Of the 30 males who consumed caffeine, their average GPA was 3.24;
> while the males who did not consume caffeine averaged a GPA of 3.13.
> Of the 30 females who consumed caffeine, their average GPA was a 3.47;
> while the females who did not consume caffeine averaged a 3.38.

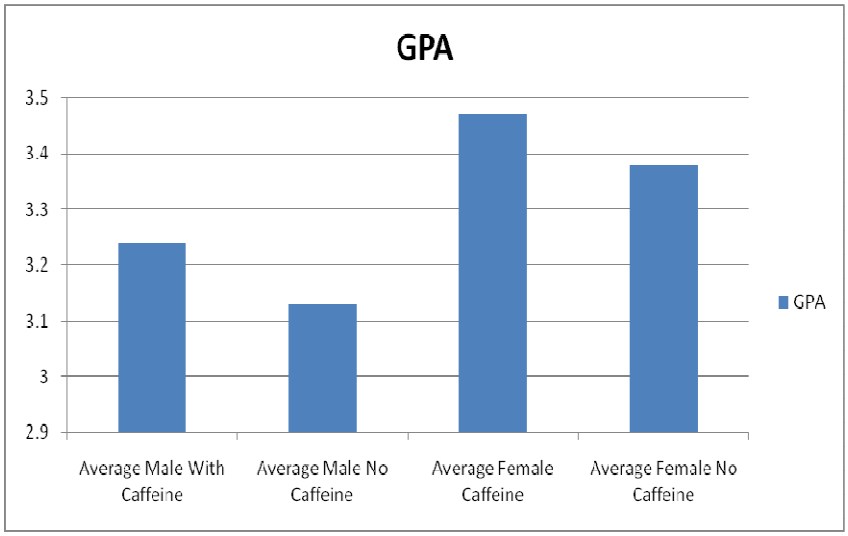


Figure 5.3: Example of a Student's Bar Chart with Inadequate Analysis

These are just examples of inadequate analysis from two students who used both categorical and continuous variables, and they presented their data using a scatterplot and a pie chart. Notice that these two examples show topics and variables that were interesting to the students: hours of sleep, GPA, and caffeine consumption; and both of them surveyed other students. In fact, Don, who did his project on caffeine consumption, surveyed 189 students (102 females, 87 males) by sending out e-mails to his classmates. The above examples show that for some students, their statistical reasoning and thinking needed to be further developed, which could not always be sustained by their interest in the topic. Although they were able to produce their visual displays of the data and calculate descriptive statistics, they still needed help in selecting the appropriate graph and in interpreting the results.

Both of the examples presented in this section are for students who presented inadequate analysis of the data that used continuous variables. The next chapter shows a particular case that used categorical variables with an analysis that was inadequate

because of the overlaps in the categories. Chapter 6 also shows two cases with adequate analysis, as well as Chapter 4 which has a single case study of an analysis that was also adequate.

5.3. Final Report of Students' Statistical Investigations (HW #4)

In the last phase of the statistical investigation, the students were required to combine the previous stages of their project and write a final report. They needed to write at least a paragraph on the following parts: (1) introduction; (2) methods; (3) results and analysis; (4) discussion and conclusion; and (5) reflection. The students were expected to revise their previous writing assignments, include the visual displays of the data with the interpretation, correct the errors in their calculations, and discuss the consistency of their results (how the results might change in various conditions), as well as the level of certainty (accuracy). Only four students out of 60 did not turn in their final report. Of those students who submitted the final report, 60.71% (34 out of 56) showed all parts of the assignment, including graphs, while 39.29% of the students (22 out of 56) missed some of the parts, particularly in showing the graphs in the results section. It is possible that some of them misunderstood the assignment and only wrote a summary of the results.

The students were required to discuss their level of certainty or accuracy of their results based on the evidence that they had. Of those students who submitted the final report, there were only seven students who did not include this part in the discussion. The majority of the students, 65.31% (32 out of 49), reported high levels of certainty because the results confirmed their hypothesis based on personal experience. The 34.69% (17 out of 49) of them who reported low levels of certainty tended to attribute this low certainty

to the sampling bias or limitation of the sample. For example, most of them wrote that they did not have the same number of males and females in their sample.

The students were also required to discuss the consistency of their results based on the following writing prompt: explain how your results might change or remain the same if you have a larger sample or if you collect the data at another site. Four students did not include this in their discussion, but the majority of the remaining 52 students wrote about how the results might change or remain the same due to a larger sample. There were only 11 students who thought about how their results might change (or remain the same) if they had collected their data at another site. There were only eight of them who said that a new location might change their results, while only three students said otherwise.

Of the 52 students, 28 (53.85%) of them wrote that their results might change due to a larger sample size, while 24 (46.15%) stated that there would be no changes in the results. Below is an example of what a typical student wrote in response to this prompt. This is from one of the case study participants named Isaac, who did his project on a comparison of the number of students who rented their books and those who bought their books. He wrote that the results might change due to a larger sample size:

> If I had a larger sample my results would definitively change because I think that having a larger number of students indicates more variety within the people answering the survey. A larger sample includes students from different social status, different age, gender, economic situation, and these are factors that make alterations to the results of the survey.

However, a larger sample size might not be representative of the population, depending on how he took his sample.

Still, other students believed that the results would not change due to a larger sample size. Recall the two students in the previous section of this chapter: Camille and Don. Camille's project was about the correlation between the number of hours of sleep per week and GPA. She wrote the following in her discussion of the consistency of her results:

> I believe because my students were chosen at random and that there were a few background questions, my data was considerably random and enlarging my sample space would not drastically change the averages and other methods of organizing my data. This leads me to be very confident on the results I have yielded and the consistent grades that the more-rested and studious students received is enough for me to believe my recommendation of sleep and studying.

Camille argued that because she randomly selected the 38 students in her sample, she believes that her data is consistent and would not change drastically due to an increase in the sample size. In her final report, Camille wrote that she collected her data at the university cafeteria because "I thought that this place would yield unbiased, fair data." However, she actually asked her friend to help her collect more data at the courtyard of a community college. Having these two locations in her data collection would have been a good opportunity for her to reflect or discuss the possible biases in her data, and how the results might have changed or stayed the same if she had only collected at the university. Furthermore, her last sentence shows that her bias clouded her thinking because she convinced herself into believing that the scatterplot she made illustrated her point.

The other student, named Don, focused on the average GPA, caffeine consumption, and gender. Recall that he had the largest sample size compared to the other students; he surveyed 189 students through e-mail. He wrote the following

explanation on how his results might have stayed the same with an increase in sample size:

> Maybe if I set it at a number like 10,000, I'd still get a more accurate reading, even if it wasn't school wide. No matter the population, I really don't believe the results would change. Like I said above, caffeine doesn't make the grades, studying and time management does. And that's proven with evidence.

In this particular case, Don was not just relying on his large sample size; rather, he was reading beyond the data and contextualizing the results of his data analysis.

5.4. Learning Opportunities and Results from the Basic Exam

Two primary data sources documented students' learning. The first one is from the students' written reflection on their overall experience with the statistical investigation (see Appendix E). The writing prompts included: "What did you learn or like about this project?" and "How might you change it or improve this study?" The second data source is from the students' performance on a written assessment called Basic Statistics Exam, which was administered at the beginning and towards the end of the semester. The following subsections are organized based on the results from these two data sources. Note that the case study interviews also have data on students' learning, but these are discussed in the next chapter.

5.4.1 Learning Opportunities from the Statistical Investigations

All students who said that they liked the project also reported that they learned something from their statistical investigation. 70% of the students (39 out of 56) said that they both learned something from the project and liked it, while only 29% (16 out of 56) wrote that they also learned something but had neutral feelings about the project, or

neither liked nor disliked the task. Only one student (1.79%) said that he did not learn anything new from the project and he also had neutral feelings about the task. Below is a summary of the results.

Table 5.9: Students' Reflection on Learning and Affective Response on the Task (N = 56)

	Learned something	No new learning
Liked the project	39 (69.64%)	0 (0%)
Neutral feelings	16 (28.57%)	1 (1.79%)
Total	55 (98.21%)	1 (1.79%)

The student who said that he did not learn anything new from the project did not articulate whether he liked or disliked the task. Here is an excerpt of what he wrote on his reflection:

> To be honest I didn't learn as much as I thought with this project. But just because my prediction came true doesn't mean that it was a bad experience. This means that I have full proof evidence to support my claim now. There are many more variables that I should have taken into account though.

It was interesting to see how this particular student interpreted learning, or lack of learning in this case, because his results confirmed his hypothesis. It is possible that he did not realize that having to think through other variables that he should have taken into account was part of his learning process.

As mentioned before, most of the students (55 out of 56) said that they had learned something. Only 30.91% of them (17 out of 55) said that they had learned specifically about statistics, statistical methods, or the process of the statistical investigation. Below are excerpts from one of these students, who reported that she learned something and liked the project.

> From this project, I have learned how to conduct statistical research, and collect and analyze evidence. I have never taken a statistics class, as I

> skipped ahead to Calculus, so I feel that this project taught me a lot about statistics. I also learned how to conduct a survey, a new way of learning that can yield factual and interesting results… I liked this project because it was an out of the box way to learn math, a subject I usually have no interest in. The conducting of the survey, and even analyzing the mathematical results was fun for even an English major like myself. I feel that the project opened my eyes to a different type of math that can be fun and knowledgeable. …For the class as a whole, I wouldn't change a thing about the project. It was quite enjoyable, and taught a lot.

This particular student is a female and an English major who had taken a calculus course in high school. Although she never took a statistics course, she appreciated learning about the process of conducting a statistical investigation. She acknowledged that this is a different type of math, and that she truly enjoyed the project.

The majority of the students, at 69.09% (38 out of 55) who said that they had learned something identified that they had learned more about the context of the study that they investigated. Below is an example from a student, named Clark, who did his statistical investigation on the opinion of American military on the controversial policy of repealing the "don't ask, don't tell" policy. Here is what he wrote on his reflection:

> This project was, and is, very close to me, due to its direct link to me. Also I find it important because it poses a meaningful question. While I had a feel for the topic prior to this project, due to the general conversations with other service members, I did not really have a firm understanding of were the military stood on the topic as a collective group. The project additionally educated me on the topic. Prior to this project I knew the policy, and its effects, however I did not know the history or the implementation of don't ask don't tell. I really liked how I had the opportunity to pick a topic that appealed to me so that I could find something that I found engaging and interesting. All too often it seems that projects are assigned without regard to the interest of the student and as a result motivation for the project is minimal causing the quality of the work to suffer. ...Overall I was surprised by how much I enjoyed this project and I learned quite a bit as a result of my research involved with the project.

Clark's written reflection shows that he had learned more about this particular topic that he chose, and that he was very motivated to work on the project. He actually collected responses from three different military sites and he had a sample size of 50 uniformed servicemen. Two of these sites, Army and Air Force, which he used in the data collection, were within a 60-mile driving distance of the university, while one of them, Marines, was located 500 miles away. He was able to obtain his data in these various locations because he is serving in the military, and he is 25 years of age, which makes him older than his peers in class. Clark had more experience and a high degree of maturity. Although he only focused on categorical variables and presented bar graphs in his report, his overall statistical investigation had an adequate analysis and was successful.

In addition to the students' reflection on their learning, the students also wrote about how they might have changed their project to improve the study. There were four major themes that emerged from what the students wrote. These are (1) increase sample size; (2) improve the survey questionnaire; (3) improve the sampling method; and (4) improve analysis. Some students wrote a combination of two of these themes when they explained the changes that they would implement. For example, Clark wrote the following:

> One thing that I have already stated which would have improved the study would have been the inclusion of Navy personnel in the sample group. Additionally I think I would have done better to poll the same number of individuals from each of the branch. While both of these would have taken more legwork I think the end result would have been a better-rounded group that would have been a more accurate representation of the whole of the military. While I don't think this compromised my results, it did however irk me quite a bit when I was doing the third homework assignment. I also think that it might have been interesting to add the level

> of education for those polled in order to see how that might have affected the results as well

Notice that Clark started to explain how he might have improved the sampling method by including the Navy personnel in the sample, and having the same number of participants in each of the four branches: Navy, Army, Air Force and Marines. He also mentioned at the end that it would have been interesting to include a question on the educational background of his participants in his survey questionnaire. This shows that Clark was reflecting on improving the sampling method and the survey questionnaire.

However, not all students responded to this reflection prompt; in fact, there were only five students out of 56 who omitted this in the reflection. There were also four students who stated that they did not want to make any changes to their project. Table 5.10 is a summary of these changes. Unlike Clark, most students mentioned only one of these themes, and the top two changes that they wrote involved increasing the sample size and improving the survey questionnaire.

Table 5.10: Students' Reflection on Changes in their Project (N = 56)

	Frequency	Percentage
Increase sample size	21	37.50
Improve the survey questionnaire	20	35.71
Improve the sampling method	12	21.43
Improve analysis	3	5.36

5.4.2 Overall Analysis of Students' Performance on the Exam

The Basic Statistics Exam consisted of 20 multiple-choice questions on the following topics: visual displays of data, measures of central tendency (e.g., mean, median, mode) and dispersion (range), relative position (quartiles), normal distribution (z-score), and regression equation (see Appendix G for the instrument). From the final

sample of 60 students, I examined their responses to the test, which was administered twice, as a pretest and a posttest. Ten students did not take the pretest, while only one student missed the posttest, which resulted in the elimination of their data on this analysis. There were also seven students who did not finish answering the pretest and only answered less than 50% of the exam. These seven students were eliminated from the final data set, along with those who did not take both tests, resulting in a sample size of 42 students with complete data on both the pretest and the posttest. The purpose of cleaning the data set was to simplify the analysis, especially in comparing both tests, which helps with the interpretation of the results.

The reliability analysis shows that the pretest was more reliable, with a Cronbach's alpha of *.7318*, while the posttest only had $\alpha = .6592$. It appears that the correct answers on the pretest were more reliable and internally consistent than those on the posttest because the pretest measured the students' prior knowledge of statistics, and thus had more variability in the responses. The posttest was administered as part of a midterm exam, a week after finishing the lecture on the statistics chapter of the book. Thus, it is possible that more students performed similarly on the test, resulting in lower variability, which results in a lower reliability because it is harder to differentiate between the low- and high-performing students. Also, there might be other sources of error, such as miscalculations or misreading the choices, guessing the answer, or using other test-taking strategies (e.g., process of elimination, working backwards by testing each choice).

Although the posttest resulted in a lower internal consistency, it had a higher average than the pretest (and a smaller standard deviation). The students averaged *9.81 out of 20* on the pretest *(SD = 3.724)*, while the posttest resulted in an average of *17.19*

(SD = 2.432). Table 5.11 shows the results of the descriptive statistics of the overall score on both tests. Results from a paired difference (or matched pairs) of subtracting the pretest from the posttest (posttest minus pretest) resulted in a significant increase in total scores with an average increase of 7.381 points (*SD = 3.305; t = 14.47; p = .000*).

Table 5.11: Descriptive Statistics of the Overall Score (N = 42)

	Mean	SE Mean	SD	Minimum	Median	Maximum
Pretest Score	9.81	0.575	3.724	2	10	16
Posttest Score	17.19	0.375	2.432	8	18	20

Thus, we can conclude that the students have shown a significant improvement from pretest to posttest. However, we cannot attribute this improvement from their participation to the project or to their having completed the statistical investigation. Because the students who chose not to participate or complete the statistical investigation were self-selected and not assigned to a control group, we cannot fully compare this group with those who completed the project.

Nevertheless, a paired *t*-test between the pretest and posttest for those who did not complete the statistical investigation or participate in any of the phases resulted in a significant increase as well. The mean on the pretest was 11.10 (n = 10, s = 3.63) and the mean on the posttest was 17.40 (n = 10, s = 4.14), resulting in a difference of 6.30 points, which is a significant increase (t = 4.81, $p = .0005$) on a one-tail test. A comparison between the students who completed the statistical investigation versus those who did not revealed no significant difference between the two groups on both the pretest and the posttest. The learning gains (posttest – pretest) were obtained within groups (project versus without project), and no significant difference between groups were detected. Table 5.12 summarizes the results, which shows that on all three independent t-tests

(unequal variance and two-tail tests), the students who completed the statistical investigation (project) performed similarly to those who did not participate in the project (without project). Although the learning gains for the group who completed the project had a higher score on the exam than the group who did not complete the project, there was no significant difference between the groups. However, it is possible that the lack of significant difference is due to the small sample size of the group who did not participate in the project and self-selection bias. Figure 5.4 also shows the box plots of the pretests and posttests.

Table 5.12: Independent t-test on students with project and without

	Pretest		Posttest		Learning Gains	
	Project	Without Project	Project	Without Project	Project	Without Project
N	42	10	42	10	42	10
Mean	9.81	11.1	17.19	17.4	7.38	6.30
SD	3.72	3.63	2.43	1.96	2.43	1.96
SE	0.57	1.1	0.38	0.62	0.38	0.62
	Difference = -1.29		Difference = 0.210		Difference = 1.08	
	T Value = -1.00		T Value = 0.29		T Value = 0.77	
	P Value = .334		P Value = .776		P Value = .458	
	DF = 13		DF = 16		DF = 11	

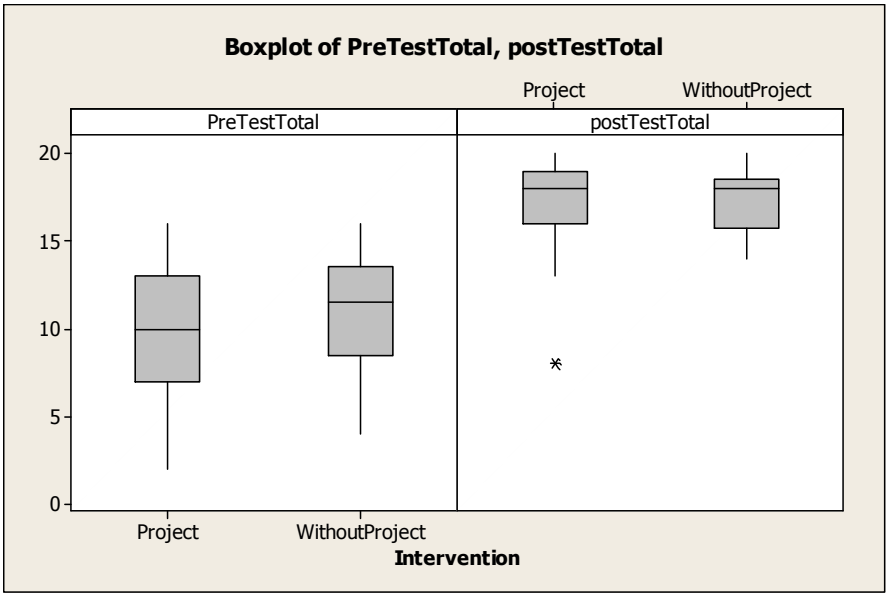


Figure 5.4: Box plot s of the Overall Scores on the Pretest and Posttest

5.4.3 Item Analysis

The table below shows the percentage of correct answers on each item. Interestingly, the highest percentages of correct answers on both tests are from questions on calculating the mean or average. On the pretest, 81% of the students correctly answered question 1 and 6; both were on calculating the mean of raw data. Similarly, the posttest showed that all students correctly answered question 1, followed by 97.6% of students who answered these items correctly: 6, 9 (range), 17 (line graph), and 18 (pie chart).

Table 5.13: Percentage of Correct Answers to the Pretest and Posttest by Item

Description of Questions	Pretest % Correct	Posttest % Correct	McNemar's Chi-sq.
1. Mean of raw data (8 data points)	81.0%	97.6%	5.14*
2. Median of raw data (20 data points)	40.5%	54.8%	1.39
3. Modes of raw data (14 data points)	52.4%	83.3%	8.47**
4. Mean of given frequency distribution	73.8%	88.1%	2.08
5. Median of given frequency distribution	16.7%	78.6%	24.04***
6. Mean of raw data—word problem (6 data points)	81.0%	100.0%	n.a.[1]
7. Mode of raw data—word problem (9 data points)	57.1%	92.9%	13.07***
8. Calculate data point of given mean and 3 other raw data	59.5%	76.2%	2.40
9. Range of given frequency distribution	54.8%	97.6%	14.45***
10. Range of raw data (6 data points)	54.8%	85.7%	8.47**
11. Calculate a z-score	26.2%	69.0%	10.32**
12. Calculate 2 z-scores and compare	26.2%	81.0%	21.04***
13. Third quartile or Q3 of raw data (30 data points)	28.6%	83.3%	19.36***
14. Box plot of raw data (25 data points)	9.5%	85.7%	30.03***
15. Predict value using regression equation	66.7%	95.2%	8.64**
16. Predict value using regression equation	45.2%	85.7%	13.47***
17. Reading a value in a line graph	76.2%	97.6%	5.82*
18. Calculate a value using a pie chart	61.9%	97.6%	13.07***
19. Identify histogram of raw data (20 data points)	31.0%	76.2%	15.43***
20. Identify stem-and-leaf display of raw data (16 data points)	38.1%	92.9%	21.04***

**p≤.05; **p≤.01; ***p≤.001 significance levels*

[1] *n.a.: test not applicable when either measure is 100%*

The lowest percentage of correct answers on the pretest was at 9.5% on the question about identifying the box plot from a raw data of 25 ordered data values, which shows that only a small number of students are familiar with the five-number summary

(minimum, first quartile, median, third quartile, and maximum). However, 85.7% of the students correctly answered this question on the posttest, showing a considerable improvement from pre to post. On the posttest, the lowest percentage of correct answers was at 54.8%, coming from the second question about calculating the median of 20 unordered data values. This particular question involves ordering the 20 data values from lowest to highest and then calculating the average of the 10th and 11th data points. Also, the numbers on this particular data involves decimal numbers, which can be confusing to some students.

The table above also shows the results of the McNemar's chi-square test (with continuity correction) on each item on the pretest versus the posttest. Most of the items resulted in a significant increase at the 5% significance level, with the exception of three items: questions 2, 4 and 8. As explained earlier, question 2 might be difficult for some students due to the multiple steps involved in answering this correctly. Question 4 involves calculating the mean for a given frequency distribution, which involves multiplying the data value and frequency, adding the products, and then dividing by the total sample size. Question 8 also involves an algebraic manipulation of the formula for the mean to calculate the missing data value based on the given mean and known data values. The actual question is as follows: "To get a C in history, Caroline must average 74 on four tests. Scores on the first three tests were 69, 77, and 63. What is the lowest score that Caroline can get on the last test and still receive a C?" During the lecture, a similar question from one of the exercises in the book was discussed, and the students were able to answer it using several strategies: algebraically by replacing the missing

scores as an unknown variable, and also by "guess and check" (or by trial and error) through the use of a calculator.

The last set of analysis involved testing for multidimensionality because the questions included examining visual displays of the data and computing measures of central tendency and dispersion, relative position, z-score and regression. The factor analysis revealed a possible two-factor structure on both tests, but the factor loadings or factor score coefficients did not group together the items that were expected to be conceptually the same. Further reliability analysis shows low internal consistencies in the two possible subtests or factors on both tests, except for the measures of central tendency and dispersion on the pretest. These are summarized in Table 5.14.

Table 5.14: Cronbach's Alpha on Two Possible Subtests

Possible Factors	Pretest	Posttest
1. Measures of Central Tendency and Dispersion (Questions 1-10)	.7113	.4025
2. Visual Displays of Data, Relative position, Z-score and regression (Questions 11-20)	.5880	.5896

Some of the items on the test were associated with the investigation were likely to have been affected by students use of them in the investigation and focus some attention on those. These items are as follows: calculating measures of central tendency and dispersion (Questions 1-10), reading a value in a line graph (Question 17) and calculating a value using a pie chart (Question 18). None of the students did a regression analysis in their investigation and few calculated a z-score or made a box plot or stem-and-leaf display. This means that the test was not a measure of students' learning from the investigation.

To summarize this chapter, the 60 students that completed the statistical investigation produced projects of varying quality. In particular, 47% of them were able to adequately analyze their data, 25% of the students provided partially adequate analysis and 28% of them were in the inadequate analysis category. This shows that 72% of the students were able to analyze their data (i.e., partially adequate to adequate), and that only a few students would need extra help to have a successful statistical investigation. The nature of the data used in the analysis was also examined, which showed that 47% of the students used categorical variables only, while 53% used both continuous and categorical variables. One of the major findings in this study is that the quality of the analysis was associated with the nature of data – or the use of categorical or continuous data. Few students were able to adequately analyze both categorical and continuous variables which raises important questions about how assignments might be designed.

Chapter 6: Case Studies

In this chapter, I start with presenting the background information of the six students who participated in this study. I highlight excerpts of their statistical investigations and our conversations from the interview that reveal their motivations. I then analyze across cases their interests, attainment value, utility, relative cost, and academic effort. I also explore what these six students learned from the project. Lastly, I end with the results from the analysis of their basic statistics exam.

6.1. Background of Participants and their Statistical Investigations

Table 6.1: Summary of the Participants and the Statistical Investigations

	Use of Categorical Variables Only		Use of Both Continuous and Categorical Variables	
Quality of the Analysis	*Student*	Topic (n = sample size)	*Student*	Topic (n = sample size)
1. Adequate Analysis	*Francine*	College students with children (n=30)	*Grace*	Grades & being in a relationship (n=40)
2. Partially adequate Analysis	*Isaac*	Renting vs. Buying Books (n=50)	*Zach*	Renting vs. Buying Books (n=31)
3. Inadequate Analysis	*Thomas*	Choosing majors (n=73)	*Quinn*	Studying Habits (n=52)

Table 6.1 shows a summary of the participants and their statistical investigations. The results presented in the previous chapter show that there is a significant association between the nature of the data (categorical and/or continuous variables) and the quality of the analysis (adequate, partially adequate, or inadequate analysis). This prompted me to examine where these six students fall in the contingency table, or how their statistical investigations are classified into one of the six themes. Fortunately, I was able to interview participants that represent each of the six profiles. All of them chose topics that

were academically related, such as study habits, choosing majors, renting textbooks, and grades. Only two students had topics that were different from the others: college students with children, a topic chosen by Francine; and the association between grades and relationship status, Grace's topic. The students' sample sizes ranged from 30 to 73.

I first present results from students who used categorical variables only, and then for those who used both continuous and categorical variables, because the students' analysis that emerged from the use of the variables differed. Francine, Isaac, and Thomas only presented the analysis of categorical variables by showing the bar graphs and/or pie charts, and they only calculated the frequencies and/or percentages. Even though both categorical and continuous variables were required in their survey instrument, these students either did not collect continuous data or disregarded it in the analysis. It is also possible that they collected a continuous variable but analyzed it by grouping the data into categories.

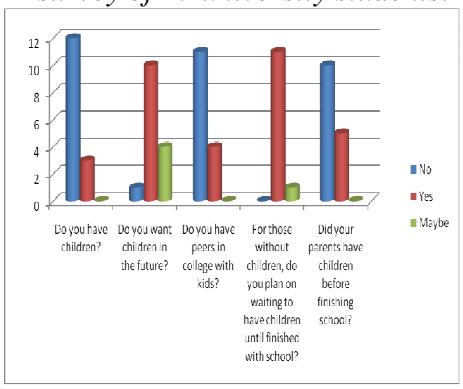
6.1.1 Students Who Used Categorical Variables Only

Case #1: Francine was in her third or fourth year in college and majoring in sociology. She wanted to get into the nursing program so that she could be a nurse at a neonatal unit at a hospital. Francine's attitude toward math could be considered neutral, because she said, *"I don't really enjoy math, but … it's not like fun for me … but, it's not that bad either … I don't hate it, but it's not fun either. So neutral. If I have to take it, I have to take it."*

Her project was about finding the number or percentage of students that are single parents in college. This topic was related to her because she was a single mom, and she had a 2-year-old son, whom she brought with her during the interview. She said, "*Like I*

said in class, I wanted to see if my guess was right that most students are not like me, and most students wanna wait to have kids after they graduate. So it was just … it was fun. And it was fun to see whether I was right or not." Figure 6.1 shows the two graphs that Francine included in her statistical investigation. Although these graphs were simple because she only focused on using categorical data, she was able to show the frequencies and discuss the results.

A survey of 15 university students:



A survey of 15 community college students:

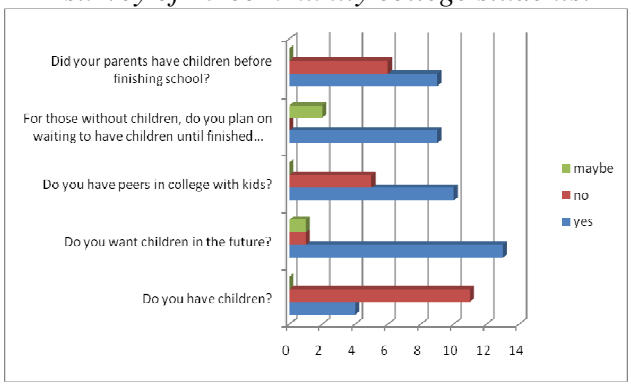


Figure 6.1: Francine's visual displays of data

Francine wrote the following results in her report from her survey of 15 university students (CSUX):

> In the study I found that 80% of the students surveyed did not have children. 66.6% of CSUX students want children in the future, 26.6% said maybe, and 6.6% said no. When I asked if the students had peers in college who have children, 73.3% said no while 26.6% of students said yes.

She then compared it to the 15 students that she surveyed at a nearby community college (CC). She wrote:

> 73.3% of students said they do not have children while 26.6% said they do. 86.6% of the students reported that they would like to have children in the future while 6.6% reported they do not and another 6.6% said maybe. Just like at CSUX, I asked the students if they had peers in college with children. This number was a dramatic difference than what I found at CSUX. 66.6% said they have peers with children and 33.3% said no.

> …At CSUX, a high majority of the students said they did not have peers in college with children. And at CC, it was almost the exact opposite. Other than these two comparisons, all of the other data was not drastically different, and was exactly what I wanted to know when creating this topic.

There were many reasons why Francine was successful in her statistical investigation. First, she mentioned that she took a statistics course in high school, but she does not remember if they had a project in that class or not. Regardless of her prior experience, Francine was the only student who piloted her survey questionnaire before the actual data collection, by first discussing her survey with the whole class and then letting them respond to a draft of her survey. She used the results of that pilot study to make additional changes to her questionnaire. Here is what she wrote on her second assignment: "In class I passed around my survey to test it out, and after getting peer feedback, I made a few necessary changes… Every question, as well as the order of questions has a relevance and purpose." Francine's only continuous variable was age of the participants, but she did not include this variable in the analysis. Overall, Francine's statistical investigation had an appropriate survey questionnaire and she was able to analyze her data adequately.

Case #2: Isaac was a dance major in his first year of college. He was also planning on getting a double major in international business because he ultimately wanted to start his own dance company. He had also learned the basic descriptive statistics in high school, which prepared him for this project. However, he did not consider himself a math person, but he had a high self-efficacy in terms of solving math problems. He said:

> *Math is not hard for me, but I just don't like it…In high school I took calculus, so, I know it's not hard, I know I can solve the… exercises, but I*

just don't like math. It's not my… [laughs]. I'm more of an art person. I like arts… yeah, I'm not into sciences that much.

For his project, he looked at the number of students who rented their textbooks at the bookstore and compared it to those who bought them. He included a table and a bar graph that shows the distribution of students who rented their books versus bought them, along with the following variables: gender, age, and year in college. His analysis and interpretation were good, but he had some errors, particularly in the third homework. After grouping the data in a table, he decided to treat the frequencies in the cells as his raw data and he calculated the mean and standard deviation. Figure 6.2 shows the contingency table that Isaac included in the report and his computations of the descriptive statistics after the table.

Here are the Results showed in a table.

Age Range	Year in school	Females who rented their books at the Hornet Bookstore	Females who bought their books at the Hornet Bookstore	Males who bought their books at the Hornet Bookstore	Males who rented their books at the Hornet Bookstore
(18-20)	Freshman	0	5	10	0
(21-22)	Sophomore	0	2	7	0
(23-24)	Junior	2	0	2	5
(24-25)	Senior	10	4	0	3

Mean= 0+2+2+2+3+4+5+5+7+10+10+0+0+0+0+0=50/16= 3.125

Median=0,0,0,0,0,0,2,2,3,4,5,5,7,10,10 = 2

Mode=0,0,0,0,0,0,2,2,2,3,4,5,5,7,10,10= 0

Standard Deviation=

Data Value	0	2	3	4	5	7	10
Deviation	-4.4	-2.4	-1.4	-0.4	0.6	2.6	5.6
$(\text{Deviation})^2$	19.36	5.76	1.96	0.16	0.36	6.76	31.36

19.36+5.76+1.96+0.16+0.36+6.76+31.36=65.72

65.72/ 7=9.38

Square root of 9.38=3.06

Figure 6.2: Isaac's visual display of data and inaccurate use of descriptive statistics

It was only after I gave him feedback to exclude this erroneous portion that he revised homework #3 for the final project and deleted the above descriptive statistics. Isaac did not have any continuous variables in his survey questionnaire, and so he was trying to create the opportunity to calculate the descriptive statistics. To a certain extent, Isaac was able to adequately analyze his data, but he had some major errors in treating the frequencies as raw data.

Case #3: Thomas was in his first year and had an undeclared major. He was planning on majoring in business, and hoped to become an entrepreneur. At the time of the interview, he was also working full time (minimum of 40 hours per week) as a manager at a Dollar Tree store. Thomas mentioned that he had taken statistics back in high school, which included descriptive statistics, probability, and inferential statistics. He said that it was more advanced than Math 1. However, his project did not include any of the inferential statistics that he learned, and he only used categorical variables.

His four homework assignments had plenty of errors and did not meet some of the requirements. In the first homework, instead of proposing several research questions, he listed some of the questions that he might ask in an interview about deciding on a major. It is possible that he misinterpreted the objective of the assignment, and went ahead with proposing a particular topic along with the interview questions. In the second homework, he also omitted his explanation on how he was going to collect his data and sampling methodology. In his final project and in the interview, Thomas revealed that he sent out his survey via email to college professors and high school teachers. In the third assignment, Thomas had some problems with his data analysis because he did not revise

some of the items on his survey questionnaire prior to the data collection. Specifically, he had some overlapping categories that made it difficult for him to analyze his data.

His topic was about the number of times that students switch their majors along with other variables, such as the year in school that they finalized their major, reasons for choosing a career path due to financial security or personal satisfaction, working students' time spent outside of school, and people who had an influence on the students' major. Below are the two bar graphs that Thomas included in his final report. His first bar graph captures the main research question that he was trying to investigate, he wrote on the caption the following: "How many times did you change your major?" with the category labels: 1-2 times; 3-4 times; 5-6 times; 7+. This particular question had overlapping categories in his original survey: "Did you change your major?" with the following choices: "A) 1-2; B) 2-4; C) 4-6; D) 6-8," but he was able to edit this. However, in the second bar graph, he wrote the following caption: "How many hours did you work while achieving your degree?" along with the following overlapping categories: 0-8 hours, 8-16 hours, 16-32 hours, 32-40 hours, and 40+hours. Thus, it is possible that he was not able to accurately capture the participants' response to this question.

Thomas wrote the following interpretation of his view of the two graphs (see Figure 6.3). Notice that his conclusions had some inconsistencies in explaining the limitations because he contradicted himself on the last sentence below, which shows that he had problems with constructing a logical argument.

> Having the ranges already made gives it limitations [in] my data. It doesn't give the interviewees a chance to show exact data… (emphasis added). Comparing both graphs helps me see… that the more classes a

person took while earning their degree, they had to work more to help pay for the costs of it. Interviewees seem to work an average of 32 hours and if the job was not giving more than 15 hours the job was not worth it. Working close to a full time job was what people have to do in today's society because how rough the economy has become… There didn't seem to be too much limitation or biase[d] opinion on this question because it was pretty straight forward and to the point (emphasis added).

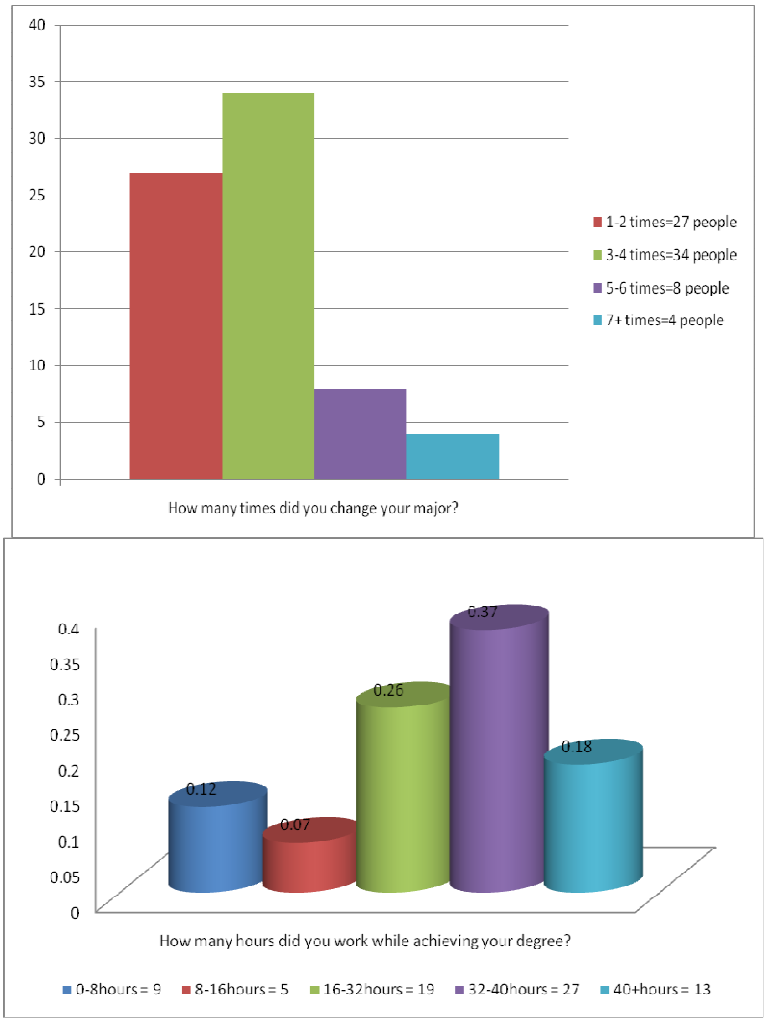


Figure 6.3: Thomas's visual display of data (inadequate analysis)

Because Thomas focused on collecting categorical data, he only presented bar graphs. The work that Thomas he presented can be classified as inadequate analysis because he had already started with some errors during the first two phases of the

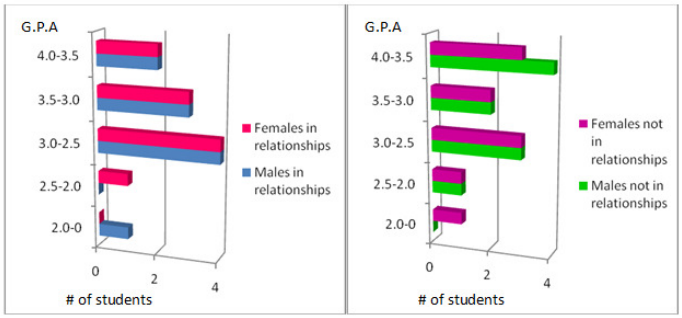
statistical investigation that he did not address. Thomas did not have any continuous variables in his survey questionnaire because he provided the choices for the respondents to circle. He did acknowledge that having the categories in his survey limited his data. During the interview, I asked him to explain the overlaps in his categories, and he said, "*Yeah, I realized that afterwards... yeah, I don't know why I did that...Yeah... that's why I messed that one… this is the one I started changing [first graph], and I started realizing what I did when you gave me the feedback*." In the end, his messy data made it more difficult for him to analyze it.

6.1.2 Students Who Used Both Continuous and Categorical Variables

Case #4: Grace was in her first year and majoring in pre-nursing. She mentioned that she had taken statistics in high school that focused on descriptive statistics only. Grace's project was very interesting and unique; it was about grades or GPA and relationship status. This particular topic was something that Grace had thought about after receiving feedback in the first phase of the statistical investigation (formulating a question), and it was not a topic that she originally proposed.

For the first homework, she proposed several research questions that were qualitative in nature and might be difficult to collect numerical data. One example of a question that she wrote is: "I'd be interested in finding out how many students under the age of 25 actually read the newspaper. Will the newspaper survive as the generations go on?" Although the first part of her topic or question involves counting frequencies, the second part of her question is more about predicting the future which goes beyond collecting numerical data and goes beyond doing a time series analysis. Her other questions also have a qualitative theme, and so I gave her feedback that it might be

helpful to ask, “How many hours do you spend per week in reading a newspaper? And how many hours do you spend per week in reading the news online?” in order to change her questions into a quantitative researchable question. After getting feedback from the first homework, she eventually proposed a new topic, which is a comparison of the GPA, grades, and study habits of those students who are in a relationship versus those who are not in a relationship. Figure 6.4 shows Grace’s visual displays of data that she included in the report.



Females in relationships

Days w/ significant other	Days spent on homework
7	2
3	7
3	5
5	3
7	5
7	3
3	3
5	3
5	3
7	7

Males in relationships

Days w/ significant other	Days spent on homework
2	4
5	7
3	3
3	3
5	3
7	7
5	3
3	3
7	4
5	4

	Average days a week spent on homework
Female students in relationships	4.3
Male students in relationships	4.1
Single female students	4.7
Single male students	4.6

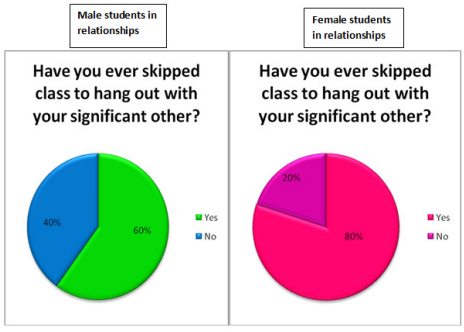


Figure 6.4: Grace’s visual display of data

Grace used the following continuous variables: number of days in a week that students spend on homework or studying, number of days in a week that students who are in a relationship spend with their significant other, and GPA. For the categorical variables, Grace used the following: gender, relationship status (single versus in a relationship), and prior experience with truancy or skipping classes to hang out with significant other (yes/no). Grace did not include the actual survey questionnaire in the second homework assignment, so I asked her to describe some of her questions. She said:

> *Okay. First I just asked if they're in a relationship or not. And then under that, I said if yes, how many days of the week do you spend with your significant other? And how many days of the week do you spend doing homework and studying so I can compare those. And I also ask them if… they've ever skipped class to hang out with them. And then if they weren't in a relationship, I ask them how many days of the week do they study. So I can compare that too. And then at the end I ask everybody, what's their current GPA. And I asked male or female, and then grade level too.*

Based on what she said in the interview, it appears that Grace collected the students' GPAs as a continuous variable, and then grouped them to show the distribution.

In her analysis of the relationship status and GPA by gender, she wrote the following results in her report:

> The average grade point average (G.P.A) of female students that are currently in a relationship is a 2.8. The average G.P.A of males that are currently in a relationship is a 2.8 as well. Because these two averages are the same, I could see that there is not a relationship between genders and whether being in a relationship has an effect on their grades. The average G.P.A of females that are NOT currently in a relationship is a 3.3 and the average G.P.A of males that are NOT currently in a relationship is a 3.8. Both females and males that are NOT in relationships have higher G.P.A averages than those females and males that are currently in relationships (emphasis added); therefore, there is a relationship between students' grades that are in relationships and that are not in relationships. The students that are not in relationships seem to do better in school,

> specifically the males seeing that their G.P.A average is a 3.8 (emphasis added).

This shows that in her comparison of the GPA by gender and relationship status, Grace was able to see that the students who are currently in a relationship had lower GPA than those who were not. Her visual display of the data, using bar graphs or histograms turned sideways, also shows that more single students (not in a relationship) are in the higher end of the distribution for the GPA compared with those in a relationship.

She also included the raw data on the number of days per week spent with significant other by gender, and the number of days per week spent on homework by gender, which should have been presented with some descriptive statistics. It is possible that she did not show the correlation between these variables because of the weak and negative association for females ($r = -0.1487$) and a low/moderate correlation for the males ($r = 0.5074$). However, she presented in the table the average days per week spent on homework by gender and relationship status. In the end, she concluded the following: "the averages of days a week single students spend on homework are slightly higher than the averages of the days a week that students in relationships spend doing homework."

The two pie charts that she presented examined the students who are in a relationship, and she asked them if they had ever skipped class to hang out with a significant other. She wrote the following conclusion:

> Clearly, well over half of the students in relationships have skipped class to be with their significant others. As we can see, females are typically more vulnerable than males to skip class. This may play into the reason why these male students' G.P.A average is higher than these female students.

Grace has demonstrated that she was able to analyze her data adequately and form valid conclusions. She used both categorical and continuous variables; she used the appropriate visuals displays of data for the different variables; and she was able to interpret these findings correctly. Thus, she was successful in conducting her statistical investigation.

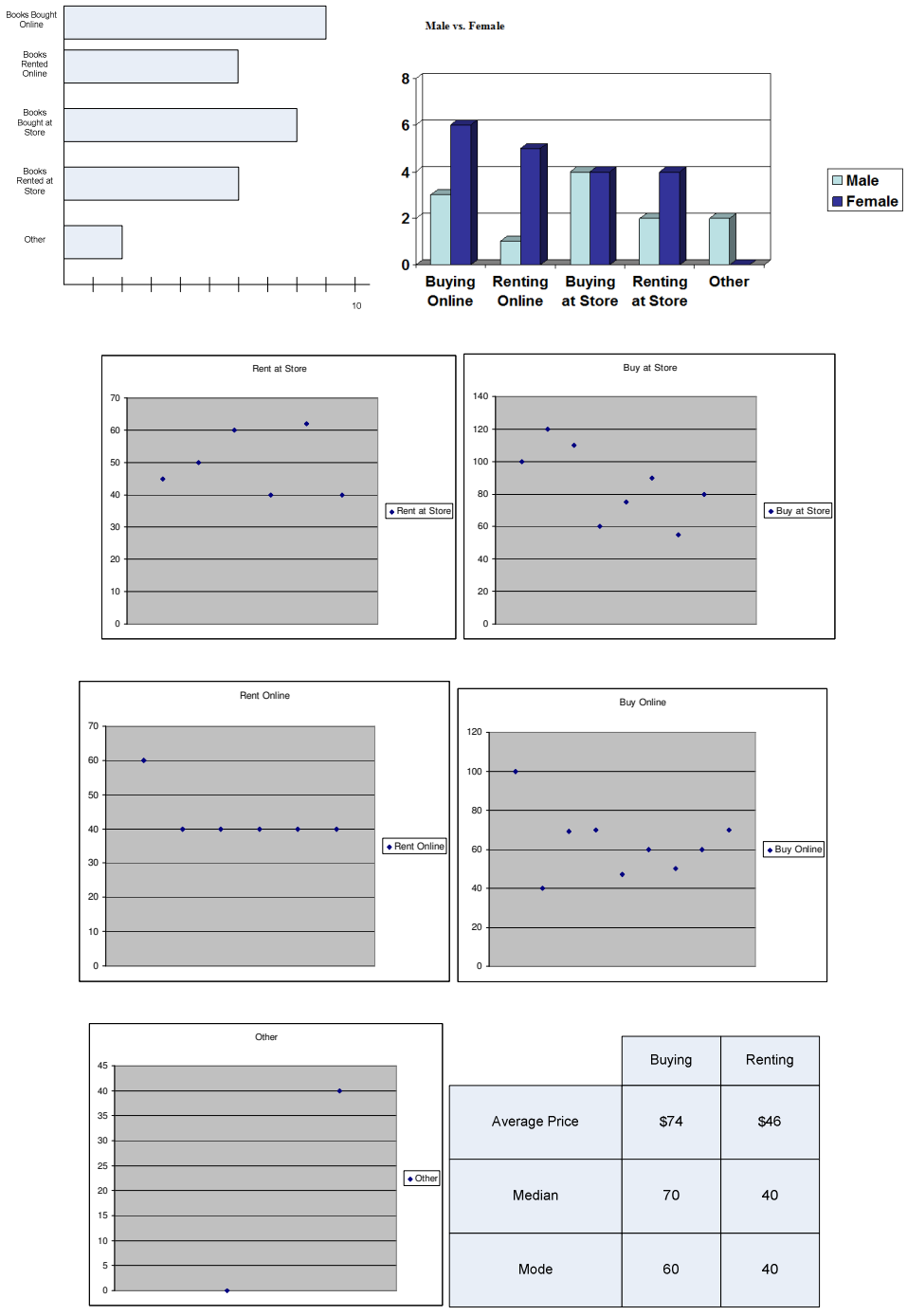
Case #5: Zach was majoring in kinesiology, and his project was about comparing the prices of textbooks that students bought or rented. This was his first year in college, and he had not taken a statistics course before this class. The math courses that he took in high school included the following: geometry, intermediate algebra, and pre-calculus. He also worked part time, around 20 hours per week, as an office assistant at a government-sponsored program.

Zach analyzed his data by showing the descriptive statistics (mean, median, and mode) for the prices of textbooks by showing the comparison between buying and renting books. He showed a bar graph of the overall data, followed by another bar graph with gender and the following ways of obtaining books: buying online, renting online, buying at the store, renting at the store, and other. It would have been better if Zach had reported the descriptive statistics on these five categories, instead of just the aggregate of those who bought their books and those who rented.

Zach decided to include the graphs of the raw data, with the prices on the y-axis, while the x-axis was unknown and meaningless. At first glance, the graphs look like scatterplots. However, the graphs were more similar to dotplots because these show the individual data points on a scale, but instead of using the x-axis for the prices, he used the y-axis instead. In all five graphs, the x-axis did not really show the frequency of occurrence, so it was not exactly a dotplot. Figure 6.5 shows the visual displays of data

that Zach included in his report, and right after is an excerpt of Zach's interpretation of the graphs, and his conclusion.

First Off: What is the most popular way people got their textbook?



	Buying	Renting
Average Price	$74	$46
Median	70	40
Mode	60	40

Figure 6.5: Zach's visual display of data (partially adequate analysis)

> On this page, one can see the various prices corresponding with the different methods of getting the Math textbook. From this data, we can see that renting regardless of where from is the cheaper way of doing things. Of course the "other" (buying or receiving from friends) is the cheapest however that is not available to everyone and therefore is a bias in itself. Renting is by far the cheaper method. There appears to be little to no difference in price when buying at the store or online and renting at the store or online. Those categories are irrelevant. Two that do matter are renting and buying. One major bias is that the data takes no note of different stores or websites. (different companies obviously have different prices).

This shows that Zach relied on the above modified dotplots to conclude that renting books is still cheaper regardless of where it was rented, online or at the store, because his descriptive statistics aggregated these two sources. His data also included the "other" category, which he thinks is a bias, possibly because it is an alternative way that students do not often consider. He could have deleted the graph for the "other" category since there were only two students in that group, and he could have calculated the descriptive statistics of the prices on the remaining four categories. In summary, there are many ways that Zach could have improved upon his analysis and interpretation.

Case #6: Quinn was in her junior year and majoring in sociology and pre-law. She had taken a statistics course at a community college last year, but she had only gotten a D-. Because she did not pass this statistics course, she was not able to transfer it to the university, and she was planning on retaking that class either at the university or back at the community college.

Quinn had experienced a similar project in her previous statistics course, but she had found some challenges with the analysis due to her variables and the data. Her project from last year's statistics class had been about the cost of buying and renting books. She mentioned that she had only collected continuous variables and forgot to ask

the students' gender and year (freshman vs. senior), and so she was not able to make any comparisons that were required for that project. This prompted her to redo the assignment and collect another set of data, and she said that she was successful in completing the project. However, based on her grade in that class, it appeared that the project had not improved her grade. It is possible that the project had other required analysis, perhaps a hypothesis test using two independent sample t-test, or that the project only counted as a small percentage of Quinn's overall grade.

As for the project in this class, Quinn had some challenges in the second, third and fourth phases of the statistical investigation. In the first homework assignment, Quinn was able to propose five quantitative research questions, and she was able to provide a rationale for each. She eventually selected the following questions for her project: "How many hours per week do students study?" and "How many college students work and how many hours per week?" However, these questions did not become apparent until the final report.

In the second homework assignment, Quinn included a survey questionnaire in the form of a table that is more appropriate in summarizing the results. Quinn wanted the students to write down the number of hours that they studied per week, on the appropriate cell of the table that describes their college level (freshman, sophomore, junior and senior) and status (full-time or part-time). There was also some ambiguity in how Quinn was naming her variables, especially in the words "academic status" and "part-time or full-time status." Below is what she wrote:

> I'm conducting a survey for my math reasoning class, here [at CSUX]. Many times professors have an understanding that the higher the academic status the more hours of study take place as well as; the greater the units

> the more studying takes place....(emphasis added) This survey is to find out if studying has any direct correlation with the amount of units and academic status (emphasis added) you are in? This will essentially give an idea of overall of about how much should a freshman student study part-time vs. full-time.
>
> Please indicate your academic standing by placing your hours of study by (pt or ft) to determine par-time or full-time status.

	Freshman	Sophomore	Junior	Senior
PT				
FT		26 hrs/wk		

In the first paragraph above, Quinn wanted to find out if the more units the student is enrolled in, the more studying take place. However, she did not even ask the number of units for which the students were currently registered. The part-time or full-time status was also unclear or ambiguous.

Quinn provided an example of a student who responded with 26 hours per week, and is describing himself or herself as sophomore and full-time. However, it is unclear what Quinn was referring to in the "part-time or full-time status" categories. Did she want to know about the enrollment status of students whether they are considered "part-time or full-time status" students? The registrar considers the number of units in defining the enrollment status of students as follows: full-time (12 or more units); half-time (6-11.9 units); and less than half-time (less than 6 units). It is also possible that Quinn wanted to know the working status of the students because that was one of the research questions that she originally proposed. In this case, full-time employment was usually defined as working 40 hours per week or more, while below that was considered part-time employment. Quinn's ambiguous categories or variable names in her survey questionnaire showed that the second phase of the statistical investigation (data

collection) was already a challenge for her, and having the chance to revise it was to her advantage.

After receiving feedback on these issues, Quinn revised her survey questionnaire and she wrote the following:

> How many hours do you study per week, on average? _____hours/wk
> How many hours do you do other things per week, on average?
> How many unit you are currently taking registered?
> What year are you? (Circle one): 1st 2nd 3rd 4th
> Age: Gender: M/F
> Do you belong to any study groups? Y/N

This shows that Quinn put in the effort to make some changes to her original survey questionnaire. However, the second question on her list was again ambiguous because she was asking for the amount of time people spent *doing* other things, which was not specific enough. On the positive side, Quinn was able to collect her data on both categorical (gender, year in college, and belonging to a study group) and continuous variables (hours per week of studying, hours per week of doing other things, and the number of units).

Quinn was not able to turn in her third assignment on data analysis and results. She included a brief introduction stating the objective of her study, and some of the results in the final project. She failed to show at least two visual displays of the data that were required. Quinn only described the results by discussing some of the frequencies and percentages that she calculated. Below is the first paragraph of her results section:

> During my study I found that on average most students do not study the required amount of time (3hrs per unit you take) 50% of students don't even study half that time. However I did find that out of 52 students 12 (5 %) of those students are female registered at full time status and 4th year students which will study the required amount of time (emphasis added) however 4 work (25% of the 12) and the other don't work (75% of the 12) but they have social lives around their schooling and studying.

Based on the above paragraph, Quinn already had some inconsistencies in her logic and some miscalculations. Her first sentence talked about her main finding that most students did not meet the 3 hours of studying for every unit registered, but the next phrase of that sentence was unclear because she claimed that 50% of the students do not study for 1.5 hours per unit. It was unclear what she meant by this statement and how she arrived at this statement given her data. She also miscalculated the following percentages: 12 students out of 52, which should have been 23%; and 4 out of 12 students, which should have been 33%. Another problem with her statement was that Quinn did not include a question on the amount of hours that the students work per week; rather, she asked a more general question: "How many hours do you do other things per week, on average?" which does not exactly convey the same message. This might have been an omission on her part.

Quinn missed the opportunity to show some of the things that she learned in her previous statistics course. She could have presented the descriptive statistics on her continuous variables, such as the mean number of hours that students spend studying per week, the mean number units that students take, and the correlation of these two variables. It is possible that her original survey questionnaire had major flaws that discouraged her from moving forward with the statistical investigation. Because she did not submit the third installment of the project, Quinn did not receive any feedback on how to improve her analysis. In summary, Quinn's poor performance on the statistical investigation began with the survey questionnaire development and continued in the analysis and interpretation of the results. There were many instances that could have

prevented this inadequate analysis, but because she missed the deadline on the third assignment, she was not able to take advantage of the feedback.

6.1.3 Summary of the Six Case Studies

Francine, Isaac, and Thomas used only categorical variables in their statistical investigations, and their work had varying degrees of quality. The statistical investigations of Grace, Zach, and Quinn were also of varying quality, but they were able to use both types of variables (categorical and continuous variables) in their analysis. It seems important to point out that Francine and Grace were both successful in most phases of their statistical investigations, particularly in the data collection, analysis, and interpretation of the results. Although Grace had to propose a new topic, both of them had very interesting topics for their projects, and their topics were very different from those of other students.

Isaac and Zach had partially adequate analysis because of the errors in the analysis and in the visual displays of the data. Isaac presented a contingency table, but he used the frequency counts as his raw data in computing the descriptive statistics. Zach was able to show the descriptive statistics for the continuous variable, but he attempted to show five scatterplots that did not have a label on the x-axis. Coincidentally, both of them picked a similar topic on how students obtain their books, either through renting or buying. The only difference is that Isaac concentrated on the number of students which he presented in his contingency table, while Zach analyzed the prices of the books as his continuous variable.

The statistical investigation of Thomas and Quinn were both classified as inadequate analysis because there were many problems throughout the four phases of the

statistical investigation. Thomas did not exactly propose a research question, but instead jumped ahead by listing his interview questions. He then submitted his survey questionnaire, but there were still problems with his categories, which resulted in a poor analysis. While Quinn was able to collect continuous variables in her survey, she only showed frequencies and percentages. There were also inconsistencies with her survey questionnaire and in the interpretation that she wrote.

These six cases represent the profiles of students to help us see that the quality of the analysis depends on the complexity of the data and variables used. It seems that the topics that the students chose were somehow related with the quality of the analysis. Both Francine and Grace chose topics that were interesting to them and different from the others' topics because they developed their research questions based on their personal experience and beliefs. While the other students chose generic topics (buying or renting books, switching majors and time spent on studying), some of these students were able to analyze their data with some feedback. Thus, the quality of the analysis and the overall success of the statistical investigation also depended on other aspects of the project, such as the students' level of interest or enjoyment with the topic of choice and their effort and motivation in completing the task. Eccles and Wigfield (2002) noted that "expectancies and values are assumed to directly influence performance, persistence, and task choice" (p. 118). Thus, it is important to examine the expectancies and values of these six students, as they can influence the quality of the analysis and overall performance in the statistical investigation. The next sections present findings from the cross-case analysis of motivation and learning.

6.2. Cross-Case Analysis of Motivation

Wigfield and Eccles (2000) suggested that identifying the motivation of students can help us better understand students' math achievement, ability beliefs, and expectancies for success. They identified the following constructs as the subjective task value that influences students' achievement related choices and performance, which I call academic effort. These constructs are interest or enjoyment value, attainment value, utility value, and relative cost. In this section, I feature the six case study participants and compare their various subjective task values and effort.

6.2.1 Interest/Enjoyment Value

Francine, Grace, Isaac, and Thomas reported high levels of interest or enjoyment from the statistical investigation, mainly because they were genuinely interested in learning more about their respective topics. Francine and Grace capitalized on their previous experience and chose topics that were different from those chosen by the other students in class. Francine wanted to know more about the percentage of college students who have children because this reflects her identity as a college student and a mother to her 2-year old son. Grace was genuinely interested in her topic as she experienced having low grades during her first semester in college because she was spending more time with her boyfriend than studying. Grace said, "*My mom was yelling at me for my grades… 'cause I was with my boyfriend all the time. So I was like… maybe I'll see if being in relationship has an effect on students' grades or not*."

Similarly, Isaac used his personal experience in picking his topic for the project. Isaac, a dance major, was an introvert but he enjoyed talking to people about his project.

Isaac was primarily interested in saving money, which is why, during his first semester in college, he learned that he could save money by renting his textbooks. He said:

> *The first thing that comes to my mind was the personal experience. You know, since I decided to do my project about how many students rented their books and how many bought them... well, in my first semester here… I didn't know that you can rent textbooks. So yeah, it comes from personal experience for me… Yeah, so I decided to do about it because... well, throughout my research, I found some students who didn't know that they can rent their textbooks. So yeah, it was interesting… And yeah, I actually did have fun, you know.*

Overall, Isaac was curious about the topic and enjoyed working on the project because it allowed him to talk to other students during the data collection process and to help inform them of an option they might not have known about. Although this was a generic topic that other students in class also chose, Isaac enjoyed collecting and analyzing the data and sharing his results with the other students.

Thomas also picked a generic topic, about choosing majors or the number of times that people had switched majors. He selected this topic at the very beginning of the statistical investigation, and he did not even propose other research questions or topics. Although it appears that his topic was in line with his situation of being undeclared, Thomas did not say that he picked this topic to inform him of how to choose a major. He said, "*I just didn't feel like choosing my major when I came into college... but thinking about it, if I take a couple more college courses, I probably will see what I really want to do*." Furthermore, Thomas said that the topic that he chose for his statistical investigation was interesting to him because "*it really showed me that people can change their majors as many times as they need to or want to, and still do what they love*."

Only Zach and Quinn reported low levels of interest or enjoyment value from this assignment. During the interview, Zach reported a low level of interest in the topic and

low enjoyment in the task by admitting that he did not like schoolwork in general and that he did not really enjoy working on the project. He said, "*Uh... out of all my schoolwork, that wasn't my favorite thing, but it wasn't bad… Schoolwork isn't my favorite thing*." He did not elaborate on any additional insights on his experience with the project in either the interview or his written reflection. It's possible that some students are not very reflective. Going back to his first homework assignment, posing research questions, Zach included only two topics, which was the minimum requirement. He proposed the following questions: (1) Which store has better prices on textbooks? Amazon.com, bookstore, or cheapbooks.com? and (2) What are the annual incomes of different physical therapists, sports doctors, and personal trainers? This last question is more in line with his major or area of interest. As a kinesiology major, Zach proposed the second research question because he was interested in those career paths. He wrote on his first assignment the following rationale:

> I am interested in working in this field and the data I research here could help me decide which job to take, or whether I should take any of these jobs in the first place. This research could help me decide on my future.

However, he did not take advantage of this because it would be more difficult to get this data. He said, "*Yeah, that would've been a lot more worse work to find physical therapists and go around to find others*." Furthermore, he said that the first topic (renting and buying textbooks) "*seemed like it would be easier to survey that than the other one*." In the end, he picked the topic that was more manageable or convenient in collecting data, and sacrificed his interest or enjoyment. As theorized by Wigfield and Eccles (1992, 2000), students choose to engage in achievement related tasks not just on interest or intrinsic value but also on the relative cost of various options. In Zach's case, this tension

between interest and cost was evident, but it was the effort or cost that drove his decision. His desire to minimize effort was evident in his completed project as well.

Even though Quinn chose a topic that she was interested in learning more about, which was the amount of time that students actually study, it is possible that she wanted to confirm or disconfirm the recommended amount of time of studying. She said:

> *'Cause the first thing that I heard from a college professor when I got here was you're supposed to study 3 hours times for each unit that you have, or something of that sort. And um, I was like, is that really true? People might—Let's just test this theory!*

She also realized that her project reflects her struggles with time management because she was working full time (40 hours per week) while taking 14 units, and she was not meeting the recommended study time of 42 hours in her case. Although she had taken a statistics course the previous year and failed, she did a project on the prices of textbooks (comparison of renting and buying). She said that if she was given a chance to do the project over, she would have picked the same topic that she collected before. Below is our conversation.

> *Interviewer: Okay... If you were given a chance to do the project over, what would you do differently?*
>
> *Quinn: I would manage my time, definitely. And I probably wouldn't do this project. [laughs] ...I would probably pick [long pause]... something easy [laughs] ...[starts reading] how many students study versus watch television?—it's very specific. Or maybe do the book thing again, 'cause that was kinda interesting for me. This is as well related to school, about how many hours are actually study—but it's more complex. Whereas, if I find out how many students, how much money students spend on books, that's just that... whether you're a freshman or a senior. You know, it's pretty straightforward.*
>
> *Interviewer: You could've picked that topic and had a basis of comparison from your previous experience.*
>
> *Quinn: Exactly, yeah. Well like this one gave me another experience, so I mean, it gave me more information. Um, definitely, if I was to do*

> *anything differently it would just be to manage my time better and... ask questions when in confusion. [laughs]*

This shows that Quinn's lack of time management probably got in the way of her success. She realized that it would be helpful to pick a very specific topic that was more interesting, straightforward, and maybe even simpler or less complicated than her chosen topic for this class. The statistical investigation brings out this tension between choosing an interesting topic versus an easier project, which are also known as interest value and relative cost in Wigfield and Eccles' (2000) framework. In Quinn's final comment she seems to be satisfied with her choice of topic but dissatisfied with her approach to completing the project.

6.2.2 Attainment Value

On the first day of class and during the interview, the students were asked to identify the final grade that they wanted in the course in order to establish their attainment goals. Francine was the only one whose goal was to get an A in class, while Thomas, Grace, and Zach wanted to get a B. Isaac only wanted to pass the class with a C because of his busy schedule. Quinn, who wanted to get a B or a C, was the only one among the six students who was on academic probation due to her low GPA and failing grades in her previous courses, which motivated her to work on the project. Although they had different goals in terms of their final grades, all students wanted to do well in the statistical investigation. In fact, all of them said that they did not even know that they could still pass the class without having to do the statistical investigation since it was only 10% of the overall grade.

Francine explained that her main motivation was to get a really good grade in all her classes, and she was willing to do all the tasks, including extra-credit work, to get a high grade. In the end, she got an A-, and she explained how she attained this grade:

> *…well, asking questions. I had a couple of those... and I wanted to make sure I did it right. So you know, come to office hours and asking how to do it.... um, helped. And formulating the questions, I looked at the paper or handouts that you gave us about how to do the homework... and then the examples that you put on [the website], just to make sure that I was doing it correctly.*

Furthermore, when I asked Francine if she knew that she could still pass the class without doing the project, she said, "*No. That I could pass without doing it? No. 'Cause if I wanted to get an A, I know I had to do all the work.... and do it the best I could. So yeah...*" This shows that one of Francine's motivation for completing this project was her high attainment value because she wanted to get an A.

In contrast to Francine's attainment value, Isaac only wanted to get a C. As a dance major, Isaac had to put in a lot of time in his dance classes and rehearsals, which left him little time to study math. He said:

> *Practices are really really long. There were days that we were rehearsing from 8 a.m. til 9 p.m., you know.... the whole day. And you will only get 10 minutes to eat something and that's it. So yeah, it requires a lot of your time. So I was thrown this semester, I was struggling not only with math but with other classes, because of dancing, you know, it requires a lot of your time. So, I was doing my best, my best to keep up with the lectures and exercises... so I was just hoping to pass the class.... yeah, seriously.*

Thus, his attainment value was low because he only wanted to pass the class with the minimum grade, given his challenges with his busy schedule. However, it was his interest in the project that motivated him to do well in the task, more than the grades. He said:

> *I wanted to do a good project. You know, sometimes you can do a project, but you're just doing it because of the grade. … I didn't do the project*

> *because of the grade, you know. I did it because it was interesting. So yeah, you know, regardless of passing the class or not, I did the project because it was interesting for me.*

Although Thomas, Grace, and Zach wanted to get a B in class, they still wanted to do well on the project. On the first day of class, Thomas was only aiming for a B. It appears that he was being realistic because he failed his two midterm exams, and he was hoping that the project would improve his grade. He said, "*Because I failed a couple of my tests and you know, …doing good on this [project]... I think it really helped me, it improved my grade*." Because the students were allowed to drop the lowest midterm exam score, Thomas' final grade was actually a B+, which was a surprise to him, and he said, "*I didn't think [it] was gonna be that high*!"

Thomas was also surprised to find out the statistical investigation was only 10% of the final grade, and that he could have passed the class without it. Thomas said:

> *No, it didn't, because I had to do it. Um... this was actually one of the things that I thought I was able to do. The tests and quizzes are sometimes like: "Oh crap. I'm not gonna pass this... I'm not gonna figure this out." Sometimes I'll be stuck on one problem for like 15 minutes, but this was easy because, you know I'm really more... after taking all my classes this last semester, I realized that typing and writing and stuff like that, it comes to me easier. It's just putting it together and finding the right words and stuff like that. So you know, that helped me, this homework really helped me.*

Because he got a B+, which was a few percentage points higher than a B, he attributed his success to the project, rather than his test-taking skills. Grace had a similar view.

Although Grace wrote on the first day of class that she wanted to get an A, she was actually aiming to get a B in this class because she thought that math was challenging for her. She said, "*I know that math isn't my best subject. [laughs] Like I normally get B's in math. So I was being realistic, I guess*." It was only after getting a

middle of the semester grade that she thought about getting an A in the class because she was already getting a B. In the end, her test scores ranged from 72 to 87, and her final grade was a B. Grace is an example of a typical female math student with low self-efficacy, even though she was able to do the statistical investigation successfully.

Grace also did not realize that she could still pass the class without the project. She said, "*Nuh uh, I never thought about that … [because] well, um, I like to do all my work, whether it's for the grade or not. It's just my performance in the class. So... I still wanted to get it done*." She explained further that she was more successful when it came to working on projects compared to taking tests. She said, "*Yeah, I think I do well on projects like, my test taking isn't as well as it should be. I think I do better on projects than on tests. So I like projects*." This shows that Grace was more invested on the project because she liked it better than taking exams. It appears that the type of task informed Grace's attainment value or whether she wants to do well on that task or not. Grace's attainment value was high when it comes to completing the statistical investigation, but when it came to her overall grade for the course, she only wanted to get a B due to her previous related experience in her math classes and her self-belief of poor ability in test taking. Even though she had a low attainment value for the class, Grace's motivation came from the interest value of doing the statistical investigation highly, which led to her success in completing the project.

Zach was not aiming for a really high grade, just enough to get a B. He said that *"A was like, ah, if I got lucky. And B is just what I wanted."* At the beginning of the semester, he said that he wanted to get an A, and that everybody wants to get an A. I asked him if his goal had changed towards the middle of the semester and he said, "*No,*

not really. If I would've gotten like… if there was any test that was like a C then probably. If I would've failed any test, then I would aim for a C probably... I know that doesn't sound good." All of his exam scores ranged from 80% to 91%, so he was performing at a B average. When I asked him if he realized that he can still pass the class without doing to the project, he said, "*Um no. I still would've done it anyways [because]…Um, I'm just that kind of person... I just wanna get a good grade... so I'm not gonna skip out on a project.*" This shows that Zach was motivated by was only interested in getting "a good grade," and so he continued with the project even though he was not truly enjoying it.

Lastly, Quinn originally wrote that she wanted an A, but later on settled for a lower goal, a B or a C. She came to class with an academic probation because she had failed her difficult classes, coupled with personal problems in her living situation. Quinn's motivation for doing the project was to pass the class. She said, "*It was important for me to do well because I feel like this was the basis of my grade, and it was something that I was actually… I thought it would be beneficial to students in the end.…*" The last part of her statement suggests that her motivation went beyond getting a good grade because she was thinking that other students can benefit from the results of her project. In this case, Quinn's statistical investigation helped her pass the class, with a grade of C, because she was getting low scores from her three midterm exams. She said:

> *I was hoping that the project would overshadow like how I was doing on my test and stuff because I'm not a strong test-taker… 'Cause the one test that I did really well on, was the statistics test with the mean, median, mode, …I was like, oh yeah, this is what I need. And everything before that, I was kinda like [grunts]—what? … And I've never even realized, this project was only 10%. I was just like you know, I gotta do good on this project because this is gonna, you know, help overlook the rest of this class 'cause this is... and that's what I was hoping, and I didn't realize it… But, I'm still glad I did it.*

Quinn was relying on the project to improve her grade. It was likely that she would have failed this class if she did not turn in any of the four assignments. In fact, she had already missed the third installment of the project (analysis and interpretation), but she was able to submit her final project in time, which earned her the points the she needed to pass.

In summary, there were varying motivations for doing the project in terms of attainment value. Francine and Zach both wanted to get the highest possible grade, which motivated them to not miss the opportunity of doing the project. Isaac did the project not just for the grade; rather, he was truly interested in this task. Although he had a low attainment value, his motivation came from the interest value of project. Grace, Thomas, and Quinn appreciated this form of alternative assessment as a way of earning points because it was different from just having their final grade based on paper-and-pencil tests. Their attainment values were already high, and they were motivated to do well in the project as a way of boosting their grade.

6.2.3 Utility Value

All six students reported high levels of utility value. Some of them viewed the project as a way of helping them think about statistics, while others focused on the usefulness of the research topic itself. Francine, Grace, and Quinn said that they found the project useful in understanding the whole process. Zach mentioned that he found the data analysis useful, while Isaac and Thomas talked about the usefulness of the project in learning more about the particular topic that they picked. All students agreed that the statistical investigation was useful, rather than just busywork or just another task that has no specific learning outcome or goal.

Francine valued the usefulness of the project, and the whole process of the statistical investigation. She said, "*We use every part of it, not like we had to write something that we didn't... that we didn't need for our project."* In other words, she valued the task because each part of the project builds on to the next. Even though the project made her do extra work, she explained, "*outside of just doing tests and quizzes*," she acknowledged that it was a different form of assessment than she was used to in her previous math and statistics courses. She also mentioned that the data collection and analysis were the most useful parts of the project for her; she said:

> *Because that's where I had my questions, and those were my answers, pretty much. It just took time... to calculate the answer. But once I got them, that was the most interesting and useful part for me... Well, definitely for my project... but for me personally, that was the most rewarding part.*

Furthermore, she valued the usefulness of the project because it gave her an opportunity to review some of the basic concepts in statistics that she learned back in high school. As a sociology major, Francine also realized the usefulness of the project in preparing her for a research methods class that she would take in the future.

Grace mentioned that the project was helpful to her in seeing the application of math and statistics to real situations. She said, "*You can actually apply stuff that you're learning to your life. So I thought it was helpful… It helps students connect what they're learning to the real world*." More specifically, Grace pointed out that the last homework assignment, which was the final project and a compilation of the other parts of the statistical investigation, was the most helpful to her in putting together the different parts of the statistical investigation. It was also the easiest because she only had to write a reflection at the end. Below is what she wrote on her reflection:

> This project was interesting because we got to choose a research question that truly interests each one of us, versus getting assigned a research question. I liked that I got a chance to use my fellow peers to help me answer my question. My research question is one that I have wanted to find out for a while now.

Thus, the statistical investigation helped her in learning more about research, and in having a really good opportunity to collect and use real data. She said that even though she does not see herself as a researcher or doing something similar to this in the future as a nurse, she said that she might get to do this in her other classes.

Quinn appreciated the usefulness of the research process because of her future plans with applying for a scholarship. She said:

> *I was actually, thinking about applying to the McNair scholarship program. And that's a research program... I feel like I can take this [project] there. I mean, hey, I've done research. I've done a study. …So I think this… is definitely beneficial… Especially if I get accepted at the McNair program. [chuckles] Oh yeah, I do see myself doing many studies from here on out. Like, it's not that bad.*

This shows that Quinn realized the usefulness of having this experience as a stepping stone to more research work. She was the only one out of the six that expressed this idea.

For Zach, the part that was most useful to him was the data analysis because "*Uh, 'cause that's the part you actually had to do... it's the one you really work on... like it's do the math*." It appears that Zach valued the usefulness of doing the project because of the learning that took place. In particular, the project was useful to him in learning descriptive statistics by doing something that was different from working through the exercises in the textbook. He said, "*If you just give homework, you know like those assigned problems... I think that's busywork. And this like you had to think… and it's useful… It kinda forced me to learn some of the material*." In comparison to assigned textbook problems, the project afforded him the opportunity to think about and develop

research questions and to work with real data that he had collected. This shows that the utility value was high, which motivated him to work on the project even though he was not interested in the topic, his level of enjoyment was low, and his attainment value was low.

Both Isaac and Thomas focused on the usefulness of the project in learning more about the topic that they picked for the statistical investigation. For Isaac, he was happy to share with the other students that renting textbooks can save money, while Thomas learned that a lot of people switched majors while they were in college. It is possible that both of them had just finished their first year in college, and they did not have enough experience with their other classes when it came to using statistics and other applications. At this point in their development, they could only focus on the usefulness of learning more about the particular topic that they chose. Isaac talked about the usefulness of sharing that knowledge to with others; he said:

> *You know what I did with some students who filled out? I told them, "Well, did you know that you can even rent your textbooks?" And some of them would say, "no." So I think that was really interesting because I could tell them... "Be sure that next semester to rent your textbook if you'd like to save some money."..* ***so that was useful for me, but to other students too.***

For Thomas, it was validating for him to talk to people about how many times they switched majors, and that this behavior was acceptable. Essentially, the topic that he chose was useful in helping him figure out his major because he was undeclared at that time. He said:

> *it was just interesting how ...there's other people in college, in their second or third year in college and say, "Oh, I don't wanna do this anymore"—and just turn around and do a whole different thing, and they spend another 3 years or 4 years in college again... trying to do what they want to do. Until they realize what they love to do in college...*

Thomas was the only student out of the six that mentioned anything about the usefulness of the project in terms of earning points for helping him attain his final grade. He said:

> *It was just a homework that would help me get my grade. But I mean towards the end, I did use more math... it really came into play when I had to do the final homework... that's when I get the 10 out of 10.*

This shows that Thomas was motivated to work on the project because he was focusing on his goal of getting a B. He also thought that the first homework assignment, formulating questions, was not very helpful to him because he already had a topic in mind, but he valued the points that he earned from it. Overall, the statistical investigation was useful to Thomas in terms of getting the grade that he wanted, which overlaps with attainment value. The project allowed him to figure out his future decisions, either identifying a college major or whether he wants to switch majors in the future.

6.2.4 Relative Cost

Most of the students described cost as the time and energy that it took them to complete the statistical investigation. They also described the difficulties or challenges that they encountered during the four phases of the investigation. Zach was the only student who reported that the statistical investigation was a relatively low cost for him in terms of time, while the other five students found the project challenging. According to Zach, he was able to successfully complete the project without much difficulty. He said that he followed the instructions closely and that the rubric was very helpful in giving him structure. He said, "*You gave us the whole rubric, and I just went by the rubric and gave what you wanted, so... almost exactly. I just did my best to follow the rubric, and everything else that you wanted*." Additionally, it was easy for him to collect the data

and to do the analysis. He admitted that he collected the data two days before it was due; thus, he did the analysis in a short amount of time because he was good at using the computer. He said, "*I didn't use Excel. I used a program called Visio. I know how to use that pretty well, so I used that for the graphs and everything*." Thus, his background at using Visio helped him in the data analysis, particularly in showing the graphs. Recall that Zach presented five scatterplots of textbook prices on the y-axis, but the x-axis was unknown. Although it appears that Zach did not have much difficulty with the data analysis, he did say that the data analysis was still challenging because the data did not have much variability:

> *Interviewer: What would you advise future Math 1 students about doing this project?*
> *Zach: Um, do something with variability.*
> *Interviewer: Okay, can you explain that further?*
> *Zach: Uh, because my project was a difficult one... it didn't vary... the data didn't vary that much so... it was kinda hard to interpret anything from it when it's all the same.*

Looking at his data again, it appears that among those who rented online, five out of six reported spending $40, which might be what he was referring to as low variability. The other graphs have some variability. Thus, it is unclear if Zach truly understood his data, and if this was a challenge for him.

At the beginning of the semester, Zach admitted that he thought that the project was going to be more challenging, and that he was stressed out. He said:

> *Uh... I was kinda stressed 'cause it was a lot of work... I wasn't sure that it was going to be difficult... but it was a lot easier than I thought… I thought the whole survey and everybody would take a lot of my time … [but, now, having done it] it was pretty easy and simple... [and] I did learn something.*

This shows that towards the end of the semester, Zach's opinion of the project changed from thinking it was difficult to thinking it was somewhat easy. Additionally, the structure of the project and the rubrics helped him in maintaining a relatively low cost because he said that he followed the rubric closely in order to earn the points. Also note that Zach selected a topic for which it was easier to collect survey data. Recall that Zach proposed two topics for his first assignment, and he settled on this particular topic because data for the other one were more challenging to obtain.

Francine, Grace, and Isaac thought that the data analysis was challenging. In addition, Francine had some problems with the survey development, while Grace struggled with the first assignment, formulating research questions. Even though Francine was truly invested in her project, she still encountered some difficulties in writing or developing her survey questionnaire, in the data analysis, and in managing her toddler while trying to work on her project. Francine said, "*The part that was difficult was making the survey... 'cause I didn't know exactly what questions to ask to get the responses that I needed.*" She was the only one in class who piloted the survey questions, and she was able to edit the questionnaire before the actual data collection. As for the data analysis, Francine had some challenges with this phase of the statistical investigation because she had to tally the responses by hand and then enter the grouped data in Excel to produce the charts. She also borrowed her cousin's computer that had Excel in it because Francine's new laptop did not have this software installed yet. She said:

> *So I was trying to figure out how to make the charts. And then I was trying to figure out how I was going to write it out or interpret the answers... so that took a little bit more time than the rest... 'cause I'm not too good with computers. So... but yeah I just did it by hand. And then I put it on the computer... in Excel ...I was working on it for awhile. But at the same time, I have a child who does this [points to toddler] at home all the time... so*

> *it's distracting. So... it took a looong time actually. He was terrorizing my room while I was trying to do it. [laughs]*

Similarly, Grace found the data analysis challenging, but she seemed to have struggled more with the first assignment. She asked her dad to help her in proposing topics for the first homework, and she asked her sister to help her on the data analysis. She thought that the project would be difficult in the beginning, but then it got easier afterwards. Grace said:

> *I thought it would be difficult, but... like when we first had to think of questions, it took me so long. I was asking my dad and I didn't know what to do. I actually didn't even put the question in here—the question I chose... I thought about it later. But, it was kinda difficult to think of questions. But once we started doing it, I realized it wasn't that hard.*

She decided to change her topic from the ones that she proposed into something completely different, which made it easier for her develop the survey questionnaire.

The challenging part for Grace was the data analysis. She said, "*I think the more difficult part was after I got all the surveys answered, it was like putting the data together and making these tables. That was the most difficult part for me… Homework 3 was really hard for me*." She elaborated further:

> *I think it was like, I didn't know how to set it up, that's all. I just didn't know how to set up all my graphs. Like I didn't know if I should use a bar graph for the GPA, or like stuff like that... I just didn't know what I should compare and what tables to make and stuff... and how to put them into tables. Like I didn't know what kind of graphs we should use for each. I asked my sister to help me too.*

It appears that Grace was fortunate enough to have an older sister who is good at math and that the two of them were able to work on the data analysis. Although Grace had some difficulties with selecting a topic for her project and in the data analysis, the second homework was easy for her because this was the part that in which had to talk about her

proposed research methodology. In her case, this might have been easy for her because her topic was interesting for her and the variables were already well defined: grades or GPA and relationship status. Additionally, her sister helped her with the graphs, which shows that she was able to offset the relative cost. Towards the end of the interview, I asked her how she felt about completing the project. She said:

> *I think it was kind of difficult, some parts. But once I got it done, I felt confident about it... If you didn't do it the way that we did it, I think it would be harder. Yeah. I think you explained it well and broke it up... it's easier. If you had just like do a survey, I think that would be harder. 'Cause I'd be like "about what?" Yeah, I wouldn't know what to do.*

Grace acknowledged that the process of statistical investigation could be daunting and challenging as a whole, but breaking it up into parts was helpful and made it more manageable. This is why she considered the final project as the easiest part because it only required her to put together the other components of the project.

The data analysis phase was also challenging for Isaac. In the beginning of the interview, Isaac said that he found the project relatively easy (or low cost). He said, "I thought of this as an easy project, especially, since during the semester, you're learning about the things that you had to do. So when it comes to your final project you already know what you have to do." As the interview progressed, Isaac said that he had had some difficulties with the analysis because he did most of his data analysis with just the calculator and manually tallied the frequencies in a table. He said that in organizing the data, "*I think that you need to be careful because if you make a mistake, that modifies your whole project. So I was very careful. I was paying attention to every detail…*" He was very concerned with accuracy and making sure that he grouped the data the right way. This was because the table that he presented had the following variables: gender,

age, year in college, and the frequency of those who rented and bought their books. Although he had an easy time with the data collection, the analysis was somewhat difficult for him.

Both Thomas and Quinn had some challenges in the earlier phases of the statistical investigation, which affected the data analysis. In particular, Thomas did not understand the objective of the first assignment because he decided to turn in specific questions that he might ask in an interview. He said, "*In the first homework …I just went straight to the [interview] questions because I knew what I wanted to do already. So I was already kinda one step ahead. And that's kinda why I got the downgrade*." He also mentioned that he had written those questions in a freshman seminar class in the previous semester, and he had not had time to think of other research questions:

> *The first one, actually, I just turned it in because out of time, and I just had to turn it in. And I had it done already, because I did in from my first year seminar class. … And then the second [assignment], … you started giving me some details on what I should improve on, and stuff like that... that's when I started getting into the homework.*

It is clear from this comment that his primary motivation was to minimize the cost of the assignment because he chose something that he knew would take the least amount of time.

Thomas also had difficulties with the second assignment because he had overlapping categories in his survey questionnaire. He also had some missing information in his assignment: for example, he did not even describe how he was planning on collecting his data. During the interview, he mentioned that he e-mailed his survey questionnaire to high school teachers and professors. He also realized his errors or the

information that he had forgotten to include in each of phases of the statistical investigation. Here is our conversation:

> *Thomas: I probably e-mailed every single high school teacher at old high school. And probably a couple here, you know, my old professors. Or somebody that I randomly picked off the email list.*
> *Interviewer: Oh, that's something that I didn't see explained in your ...*
> *Thomas: Oh, I don't think I did that, huh….So that's why I really got marked down on some of the stuff because I started seeing what I did wrong, you know. After one homework after another, you know, you started giving me more feedback, and that's when I realized, you know... oh I see what she's talking about now. I started going into the homework and actually, you know, there's still things I can work on... and if we had another homework assignment, I'll probably improve a lot more on that one.*

This shows that Thomas actually went through the trouble of sending emails to teachers to get his survey data. This took more time than surveying the other students in class. So while he did not put a lot of time into other aspects of the project, this shows that actually had to put more time and energy in compiling the email data than most. However, it is possible that he did not view that work as time consuming because he did not articulate this during the interview.

Similarly, Quinn had some problems with the second assignment because she was paying attention to the format of the survey questionnaire, rather than the validity of the questions. She said, "*How am I going to format this to ask people? And I had came up with some—like chart. That just was not working out*." Recall that Quinn provided a table where she asked the participants to write down the number of hours that they studied per week. But first, the participants had to select a particular cell on the table where they would write the response, which depended on the year in college and whether they were full-time or part-time students. After receiving feedback on the second assignment, Quinn

said that she was able to understand her mistakes and how she way trying to complicate things for herself. She said:

> *And then, when I got your feedback you were kinda like—do it like this... you're gonna breakdown how many hours per week on average, you know. And then how many hours do they do other things, on average, and how many units are they taking. Are these people female or male? Are these, are they first year, second year, third year or fourth year students. And that made it a LOT more simpler for me. So, that was the first thing. 'Cause I kinda had made a stand still—when I was doing my homework 2, I was kinda like... and maybe that's why my thoughts were incomplete... I just couldn't figure it out. And once you gave me the breakdown, of how you thought I should do it, I was like... that makes way more sense. I was making it too complicated.*

For the data analysis, Quinn also had some challenges with it because she admitted that she was not familiar with using Excel. She said, "*I did everything basically by hand and a calculator*." Quinn also mentioned that her boyfriend helped her with some of the calculations, particularly in calculating the percentages. Unlike Grace, who asked her sister for help in the data analysis and, with her sister's help, was able to adequately analyze the project, Quinn's project was unsuccessful, even with the extra help. Quinn did not even submit the third assignment (data analysis and interpretation); instead, she included some of the analysis in the final project. Her final report had a lot of missing details in the analysis, and she did not include any of the required visual displays of data. This shows that Quinn's motivation to do well on the statistical investigation could have been negatively affected by the difficulty of the task or high relative cost, which is evidenced by the inadequate analysis of her statistical investigation. Pajares (2006) noted that "academic work should be hard enough that it energizes, not so hard that it paralyzes" (p. 344). In Quinn's case, the relative cost of the task paralyzed her and prevented her from having a successful statistical investigation.

6.2.5 Academic Effort (Achievement Related Choices & Performance)

This section is closely related to the previous one, relative cost, because the students described the amount of time and energy that they expended in completing the investigation. There were several indicators of academic effort that I looked for, such as completed parts of the project, the students' progression from one assignment to the next, and revisions that they made. Francine, Isaac, and Grace had these indicators of high academic effort, while Zach, Thomas and Quinn seemed to have put in low effort and less time in their statistical investigation.

Francine was very resourceful and she was able to overcome her challenges in data analysis and survey development, which resulted in her successful completion of the project. She was able to overcome these challenges by accessing her previous experience with working on projects, and by relying on the advice or help of others. She mentioned that she had had some experience with other classes that required projects (e.g., communications courses), but she appreciated the structure that the project for this class provided; She said:

> *Yeah, I've done a lot of projects... but this one was broken up into parts... so it was a little bit more time consuming... but also it was better in the end 'cause all my information was right there... And you make sure you get it done, 'cause you're doing it on increments. So it was good.*

This shows that she capitalized on the structure of the project. Recall that she ran a pilot test of the survey questionnaire, which helped her in refining her survey. She also came to my office hours to get some help on the survey development and analysis. Her advice to other students: "*If they needed help, or even just finding questions or anything... just*

use all the resources that they have.... teacher's office hours, looking at the information that's available to them... make sure that they don't do everything at the last minute."

Because of the challenges that Grace experienced in proposing several research questions, in selecting a topic, and in the data analysis, she asked for help from her dad and sister. The research questions that she proposed in the first homework assignment were not very interesting to her, and she put in the time and effort to think about another topic that might be suitable and motivating to her. Recall that she changed her topic for the second homework, and was able to collect her data successfully. She also had difficulties with the data analysis, but she asked for help and she was successful in showing the graphs and in explaining her data. Her homework is a reflection of the time and effort that she put in working on the data analysis. During the interview, I asked her if the amount of time and effort that you put in was worthwhile for her. She said, "*Yeah. I think it was. I did put a lot of effort into this, so yeah*." Her advice to other students when it comes to working on the statistical investigation is, "*I would say, if you get confused, ask for help. 'Cause I got confused on what question to pick*."

Similarly, Isaac put in a lot of time and effort in the project. He included a lot of the feedback from the previous homework, and he was very careful in constructing the contingency table or grouping the data. He wanted to make sure that he was accurate in his calculations of the mean and standard deviation, although these were unnecessary. He put in extra work that was not accurate, but he removed that part for the final project.

Zach, Thomas, and Quinn seem to have had some struggles with putting in the time and effort into the statistical investigation. Because it was easy for Zach to collect the data and to report the data analysis, he did not put in a lot of time and effort into the

project. He said, "*'cause I only had a couple of days before it was due, so... after that I was fine… I didn't think that it would take that long to do the data collection. I thought that it would be easy to get it at that amount of time*." When I asked him why he waited until it was almost due to collect the data, he said:

> *I was busy. I was having trouble with my English... so I was trying to fix that grade, and I work too, so just busy. I was taking English, public speaking—which we make speeches and stuff, and the last one was biology—which I also had a bad grade for a while...*

For Zach, his other classes took priority over this math class, and because he was not failing in class, he did not put in a lot of time and effort. Furthermore, he said that *"I procrastinate a lot, but I got them done. I had a lot of speeches. I had a lot of papers.... I had another project... English papers and speeches to write, that kind of project in those two classes*." This shows that if the statistical investigation had not been broken up into four deliverables, it is possible that Zach might have procrastinated in doing the whole project. His progression from the first homework to the second shows that he put in some effort in revising his question, and he incorporated some of the feedback in improving his questionnaire in the second homework. For the third homework, data analysis and results, he said that "the analysis wasn't that hard for me. I just sat and did it for like 4 hours… I'd say like 4 to 6 hours. I did that all in one time." This shows that Zach did not find it difficult to analyze his data and that it did not require a lot of time and effort on his part.

Thomas and Quinn had some challenges with managing their time or meeting the deadlines, and in understanding the tasks in the various phases of the statistical investigation. Both of them were registered as full-time students, with around 4-5 classes, and also were working as store managers at 40 hours per week, which is considered full-time employment. Both of them struggled with balancing their responsibilities at work

and at school. Quinn said that "*I definitely would do things differently. I definitely don't want to work full time, while going to school. Although I know I needed to support myself. But …maybe something that is not as strenuous as a management position*." As a result, both of them struggled throughout the four phases of the statistical investigation. The inadequate analysis that Thomas and Quinn presented in their third and fourth assignment reflects their lack of time and effort.

Thomas did not put in a lot of time and effort in his project because he was busy with his other classes and he was also working full-time. He said that his biggest challenge is time management. He said, "*It's just managing and getting it on time, that was pretty much it. I've been dealing with my [responsibilities] …and just turning it in on time*." This shows that Thomas struggled with finding the time to work, but it is unclear if Thomas struggled with the data analysis. Still, it took him a day or two to complete the data analysis part of the assignment, and he said that it took him two hours to produce the graphs. As for the earlier phases of the statistical investigation, particularly in the data collection, he said:

> *I sent out the e-mails... I did the surveys, it probably took me half an hour to an hour, thinking about what I wanted to ask and stuff like that (emphasis added). And then, I would sendt out the emails, and come back home at night and check my email, and they would all be there and done already. I just had to put it together, put the numbers together, something like that.*

Unlike Francine and Grace, Thomas did not put in a lot of time and effort in the statistical investigation. He could have spent more time in developing his survey questionnaire, rather than just putting in an hour writing his survey questions, and he could have avoided having the overlapping categories. Although he did have a large sample size

(n=73) because he collected his data via e-mail, his dataset had some problems, which made it difficult for him to analyze it.

Quinn also had some problems with managing her time and in following the rubric. It appears that she was able to put in more time and effort on her first assignment, because she proposed five research questions and she provided the rationale. She seemed able to put in more time and effort during the first phase of the statistical investigation, perhaps because she was not working full-time yet. She said:

> *Well before like, before I started my job, I was probably studying like, I was spending a hard core time in the areas where it needed. So like, math, I was probably studying each day. You know, especially on Tuesdays and Thursdays, 'cause I would try to go to the math lab after school, after I got out of classes. I'll be there at the math lab for like, um, 3 hours. … Then when the job started, I was kinda like... oh, as long as I can do the assignment in math or in econ. Yeah.*

This shows that Quinn had more time to study at the beginning of the semester, when she did not have a full-time job yet. When she got the job, her schoolwork suffered.

In the second homework assignment, she did not meet the requirements because she did not discuss her proposed data collection and she provided a table instead of the questionnaire. She also missed the deadline for the third assignment, and it was unclear if she was able to maximize her time and effort in working on the data analysis. Below is her description of her work process on the data analysis; she said:

> *I was stopping and going... [laughs] It was actually... it took me... I started on it one day, and I worked on it for maybe about an hour or so... it was on a Saturday… And I worked on it for maybe about another... 2 and a half hours or so.*

It appears that Quinn spent 2 days with a total of 3 to 5 hours in doing the data analysis, but she was stopping and starting in the middle of the project, which is an indication of low motivation. Towards the end of the interview, Quinn said, "*I think I was just lazy at*

one point, and um, just not being able to understand what it was that I was being asked... or what was desired from me." Even with her boyfriend's help, her statistical investigation was unsuccessful because she did not understand the objectives of the assignment; this was coupled with her low motivation. In hindsight, Quinn explained that she would definitely manage her time wisely.

> *When I got to college it was like, whoo... time manangement, you know. When do I have time to study? How much am I supposed to study? … So I think if I was to do it over, I would definitely plan my time out better. This would be a good project to do. But I would, you know, come back to you for feedback or comments.*

It was interesting that Quinn's statistical investigation looked at the amount of time students spend in studying, and yet she struggled with this issue herself.

6.3. Cross-Case Analysis of Learning

With the exception of Zach, all students reported that they had taken a statistics class in either high school or college. Francine, Grace, and Isaac had been exposed to descriptive statistics only in high school. Thomas and Quinn had taken a statistics course that includes inferential statistics in high school and junior college, respectively. However, Quinn had failed the course with a D-. It appears that Thomas and Quinn did not capitalize on their previous statistics courses because of their inadequate analysis on the statistical investigation. Francine, Grace, and Isaac said that this class gave them an opportunity to review of some of the basic concepts in statistics that they had already forgotten. Zach reported learning more about the process of the statistical investigation.

Both Thomas and Quinn wrote their reflection on learning about their increased understanding of the topic that they chose, rather than on their learning of specific statistical concepts. Below is an excerpt of what Quinn wrote on her reflection:

> What I learned through this project is that I am one of those students who has not quite learned the systems and resources of college (emphasis added). I personally work full time 40 hrs a week and go to school full time taking 12+ units and only study maybe 15 hours a week and that is only 1hr15mins per [unit]. This is definitely a problem because my performance could be much better (emphasis added). However, I found that by doing this study it is essential to follow the required amount of study in order to succeed. I am a 3rd /4th year student and I plan to do another study of my own next semester to see if there is a difference in the stress level I have and my grades in my classes. I definitely learned that studying gets more and more important the closer to graduating the student gets.

Quinn also reiterated this during the interview when she said: "*I think each project can teach us something... maybe I should take studying more seriously. Or maybe I should integrate that with my time of things that I need to do*." This shows that the statistical investigation had some impact on her thinking about her own study habits.

Thomas expressed a similar learning experience through the statistical investigation by focusing on the topic and the changes that he would make based on his experience with the data. He wrote:

> I liked this project because it gave me an insight of what to expect of a major that can make the difference in something I love to do and something that I will have to do (emphasis added). It shows me the choices people make between financial security and personal satisfaction can make a difference in people's career choices. I also learned that it is more important to do something that I would love to do, rather than doing something that I will regret later on in my life (emphasis added). If I can change this study in one way, I would give more options to the scenarios that I set. I would also give a couple more open-ended questions to gain a better understanding of surveyors that would like to give an explanation of what they were thinking or trying to achieve during their process of earning their degree in their major. Within this study I have learned that not only does many take into consideration their future financial need, but also their satisfaction of what they will be doing for years to come.

This shows that Thomas actually learned from the mistakes that he made in the beginning stages of the statistical investigation. In particular, he said that it would be a good idea to

give more options or have open-ended questions. It is possible that he realized this because his original survey questionnaire had only categorical variables with overlaps. He also wrote about the insights that he gained from the topic that he chose, and hopefully this was a way for him to figure out his major. These are important learning milestones for Thomas considering that his motivation was to get a B in the class, and his primary consideration for his investigation was to earn points toward his grade.

In fact, during the first week of the semester when he found out that there was a class project, he immediately had a negative view of this task. He said:

> *Uh, I was thinking, "oh crap, it's a math class, why do we have to do all this stuff?"—you know. <u>But I started realizing how much it really works in class, and you know, towards the end you see why we did all this</u>* <u>(emphasis added)</u> *and stuff like that. But in the beginning, I was like you know, why are we doing all this extra work? Like any typical student, why do we have to do a project?*

This shows that he learned about the process of statistical investigation because he started to see how the different parts of the project fit together. After completing the project, Thomas felt that the learning was worth the effort since he alluded to "*realizing how much it really works*…" This can be interpreted as an emerging understanding of the survey process. He said, "*Surveys are gonna be more and more there... and research... so we're gonna have to do more of that... that's gonna be in almost every class—researching and taking a topic you wanna or learn about*." In line with Lave and Wenger's (1991) theorizing that "one way to think of learning is as the historical production, transformation, and change of persons" (p. 51), Quinn and Thomas seemed to have learned from the statistical investigation because they were able to realize something about themselves through the project.

Zach, Francine, Grace, and Isaac also expressed that they learned more about survey research and the process of statistical investigation. When I asked Zach to elaborate on what he learned in doing the project, he pointed out some of the important concepts. He said that he learned "*the different kinds of variables like the graphs and everything.... the categorical and stuff like that... and everything about sample sizes, how many people you need to have a decent sample... and how it all ties with the large group… and how to make a successful survey*." He also said that he could see himself doing a similar project in his other classes before graduating. In his final report for the project, he wrote the following reflection:

> I learned a lot about taking surveys and what you need to complete them (for example survey size). It also taught me about the variety of graphs one can use. That made everything a lot easier. I would add a larger survey size to improve this study. After getting a larger amount of participants, I would add more categories and go into depth on which places are the cheapest to get a textbook and how.

Thus, it appears that Zach learned about the process of statistical investigation, particularly in presenting the data through graphs and descriptive statistics, as evidenced by his written project. His reflection shows that he realized that his sample size of 31 was small, and that having a larger sample size can improve his study. Although, Zach was able to mention three statistics terms ("*the different kinds of variables, graphs and everything... the categorical and stuff like that...*"), his statement and written reflection do not show strong command of the ideas behind these terms. This means that Zach is at the beginning stages of understanding survey research because his statements are a bit vague.

In contrast, Francine wrote her reflection on learning how to develop a survey questionnaire. Recall that she was the only student in class who conducted a pilot study,

which helped her in refining her survey questionnaire, and she also presented her findings in class. She wrote:

> Based on the results I received, I was able to see that most students are not like me, as I explained in my power point presentation. What was similar to me however was that most of the students had parents who had children outside of finishing their academic goals…. What I enjoyed about doing this project was interacting with people, learning how to create an effective survey to get the results I need, and finding the answers to my question (emphasis added). I accomplished all of those tasks.

Grace also had a positive learning experience with engaging in the statistical investigation. Unlike Francine, though, Grace does not say that she learned something about herself. Rather, she emphasized the link between learning about statistics and doing statistics. She wrote the following reflection:

> I'm glad that we got to do this project because it was a fun learning experience. We didn't only learn the material but we got to exercise it and use it in everyday life. It made us connect what we are learning in class with the real world. I wouldn't change anything about the project. I felt like it was a good experience for the entire class.

During the interview, Grace disclosed that she was enrolled in an elementary statistics course because it was a required course to get into the nursing program. She was looking forward to learning more about statistics and believed that this class would better prepare her for that class.

Lastly, Isaac also wrote about his positive experience with the statistical investigation and how it helped him in better understanding some of the statistical concepts that he learned previously.

> I really enjoyed doing this survey because besides the mathematical side of it; it gave me a perspective about how students are being affected by the raise on the tuition, and what things are being done by some students to save money. Doing this type of survey it also allowed me to get a better

> understanding of mathematical concepts such as median, mode, standard deviation, and frequency (emphasis added).

This shows that Isaac valued learning about his topic, and that it seemed to be equally as important to him as learning to apply statistics. He was specific about both aspects of learning: (a) about his topic and (b) about statistics.

Because some of the students had taken some statistics in high school, it is worth noting the concepts that they remembered or had forgotten, and how this class helped them develop a deeper understanding of statistics. For example, Francine mentioned that she had taken a statistics course back in high school, but she claims that she had already forgotten most of what she had learned in high school. She does not remember if she did a similar statistical investigation or project in her high school class. As for this class, she mentioned that she had learned the following concepts: "*like the percentages, the mean, median and mode... [but] it was review... [laughs] ... I just haven't seen it in a long time... [laughs]*." Even though she had forgotten some of these concepts from her high school class, she appreciated the opportunity to review and apply these concepts. Because the project that she did was related to her situation and her son, she said that she would more likely remember her experience with this particular project. She said, "*Yeah, I'll remember this. I think I'll remember college material. And because it relates to my life... like this relates to my son... I'm most likely to remember this project*." In the end, she said that she was able to confirm her hypothesis that only a small percentage of college students had children, making her circumstances somewhat unique.

When it comes to learning statistics, Grace said that she took precalculus in her junior year, and statistics in her senior year of high school. She said "*We did kind of the same stuff we did in this class. So I was like, oh we learned that in statistics! Yeah... We*

did... like the mean, median, mode.... standard deviation and the z-score, we did that too." I asked her if it was an advanced placement (AP) statistics course, and she said that it was not an AP class because it only had the basic descriptive statistics. She added:

> *Grace: Yeah. And we did the box—*
> *Interviewer: The box plot?*
> *Grace: Yeah, the box plot. So a lot of stuff was familiar.*
> *Interviewer: So, similar to what we did here in class. Did you feel like it was a repetition of what you did back in high school?*
> *Grace: Well, not really a repetition. It's just... 'cause I think I learned it more in the Math 1 class. Like more of it... or harder, more difficult problems than what we did.*

As for the project, Grace said that she was able to apply what she learned back in high school and some of the things that we did in class. She said, "*In doing the project... um, it was kinda basic math, so I kinda knew all of it. Like the mean, median, mode—I knew that*." Furthermore, she liked that the project required her to show at least two graphs and visual displays of data, and even recommended increasing the minimum requirement for the number of graphs. She said:

> *I think it was helpful to have more graphs... like visuals, so you can like look at it and explain about it. That helped me. So that's why I have 4 graphs... 'cause it helps. So the more you have, the easier it is to explain your data. Well, for me it is 'cause I like to see.*

Interestingly, she found it challenging to do the data analysis and to create the graphs, especially in figuring out what variables to graph. And yet, this was the part that was most helpful to her learning process. Even though the Math 1 class was a good opportunity to review the basic statistics that she learned in high school, she still found it helpful in reinforcing the concepts.

In Isaac's case, he probably learned from his mistakes in the data analysis. Recall that Isaac's data only contained categorical variables, and he tallied the number of

students who rented their book and those who bought their books by gender, age group, and year in the program. He then proceeded to treat these frequencies as his raw data by calculating the mean and standard deviation, which is a major flaw in this analysis. Later in the interview, he mentioned that he had learned how to calculate the standard deviation back in high school but had forgotten about it until this project.

> *Interviewer: So what was something new that you learned in doing this project?*
> *Isaac: Umm, it wasn't new but I didn't remember. I saw this type of exercise in high school, but it's been a while since I took the course. Something that I didn't remember at all was the standard deviation. That was something that wasn't in my memory anymore.*
> *Interviewer: You forgot about it?*
> *Isaac: Yeah, I totally forgot about it.*
> *Interviewer: So this helped you in remembering some of the concepts?*
> *Isaac: Yeah...*

Thus, the project gave him the opportunity to review some of the basic descriptive statistics that he learned back in high school, albeit procedural knowledge of basic statistics. However, his lack of conceptual understanding is evidenced by his erroneous application of the standard deviation. His final project removed this major error, and perhaps he learned the inappropriateness of treating the frequencies as raw data, even though he did not overtly say this.

In summary, Francine, Grace, and Isaac talked about the enjoyment that they got from the statistical investigation. Zach focused on the usefulness of learning more about research, while Grace focused on the application of statistics in answering research questions. Although Francine and Isaac had taken some statistics courses in high school, their prior knowledge did not have the depth of understanding that helped them in recalling and applying the appropriate concepts. Grace was the only one who was able to transfer her prior knowledge of statistics to the project, which is one of the reasons why

she was successful in analyzing both categorical and continuous data. All students reported that they appreciated having the chance to apply what they were learning to real world contexts. In the case of Thomas and Quinn, they learned more about topic that they chose, while the rest valued the application of statistics.

6.4 Case Studies – Performance on the Basic Statistics Exam

It was interesting to see that the six students who took the pretest were able to calculate the mean (Question 1 and 6), which shows that they already have some basic knowledge of descriptive statistics even before conducting the project. Grace and Zach had high scores on the pretest, 16 and 11 out of 20, respectively. Grace's pretest had errors on the following: calculating the mode of raw data, median of a given frequency distribution, z-score and identifying the box-plot (items 3, 5, 11, and 14). It was also surprising to see that both Grace and Zach were able to answer the two questions on predict a value using regression equation (items 15 and 16).

Examining the errors on the posttest reveals that four of these students (Isaac, Thomas, Zach and Quinn) incorrectly answered question 2, finding the median of a raw data. Question 5 is also about finding the median of a given frequency distribution, and three students missed this too (Isaac, Thomas, and Grace). Two students missed question 11, on calculating a z-score (Isaac and Thomas), but one of them (Thomas) was able to answer question 12, which was more difficult because two z-scores had to be calculated and compared, while the other one missed it. Only one student from this subsample, Isaac, incorrectly answered questions 19 and 20, on identifying the correct histogram and stem-and-leaf displays with the given raw data. Another student missed question 8, on calculating a missing data point given the mean and the remaining data values.

All six students improved their performance from pre to post, with the exception of one student who did not take the pretest. Table 6.2 has the overall score and the descriptive statistics. It appears that Quinn had the highest increase in score (learning gains), 11 points, followed by Thomas and Zach (at 8 points increase). Even though Thomas and Quinn performed poorly on the statistical investigation, their scores on the posttest were good. Grace had the lowest change in scores, mainly because her pretest was already high at 16 out of 20. Isaac had the lowest posttest score at 14.

Table 6.2: Case Studies – Performance on the Test

	PreTest Score	Posttest Score	Learning Gains	Incorrect Questions on the Posttest
Case #1: Francine	n.a.	18	n.a	3, 8
Case #2: Isaac	9	14	5	2, 5, 11, 12, 19, 20
Case #3: Thomas	8	16	8	2, 3, 5, 11
Case #4: Zach	11	19	8	2
Case #5: Grace	16	19	3	5
Case #6: Quinn	8	19	11	2
Mean	10.40	17.50	7.10	
Standard Deviation	3.36	2.07	3.08	

In contrast, all students correctly answered the following questions: 1, 6, 7, 9, 10, and 13 to 18. They were able to answer questions about calculating the mean and range, as well as the quartiles and the rest of the five-number summary in order to correctly identify the box plot. Interestingly, all of them were able to answer correctly the two questions on using the regression equation to predict the value. As for the visual displays of data, the six students were successful in reading the line graph and pie chart, as well as in computing the frequency given the percentage from the pie chart and the total sample.

To summarize this chapter, the case studies show variations of students' statistical investigation and their perspectives on various aspects of their motivations for the projects. Francine, Grace and Isaac truly enjoyed the statistical investigation and their

motivation was influenced by the high interest value that they placed on the project. All six students reported high levels of utility value because the statistical investigation helped them to think about statistics, and the research topic that they picked was useful to them. Also, all six of them wanted to do well in the statistical investigation. However, they had varying levels of relative cost and academic effort. In particular, students who found completing the investigation to be costly in terms of time and effort were students who investigated generic topics, such as the cost of text books, switching majors and hours of studying. Their motivation to explore the topic was not strong enough to fuel persistence.

Chapter 7: Discussion & Conclusion

The purpose of this study was to explore the reciprocal relationship between statistical investigation and motivation. In this concluding chapter, I summarize the findings, discuss the interpretation of these results, and present the conclusions and recommendations. I also address limitations and potential future work in this area. The research questions that guided this study are as follows:

1. What do students' statistical investigations look like based on their written work during the four phases of the investigation?
2. What strategies do students use in analyzing their data? Which categorical and/or continuous variables do students use in the analysis and how do they analyze the data?
3. How do students' levels of motivation, in particular, their subjective task value, result in the completion of the statistical investigation or academic effort?
4. What statistical learning do the students show or articulate after conducting the statistical investigation?

7.1 Summary of Findings & Discussion

This study examined the statistical investigations of students in a mathematical reasoning course (Math 1), who were given the opportunity to formulate their own research questions based on their interest, develop their own survey questionnaire and collect data, analyze and interpret the results, and showcase their work in a final report. My hypothesis was that students would pick topics that had such high subjective task

value that each student would do a distinctive study that they would be excited about. This excitement would help them overcome the cost of doing the study, in particular the time and effort that the investigation required. There were three major findings that emerged through this study. First, although the students were required to collect both categorical and continuous data in their survey, some students only collected and used categorical variables. Second, there is a significant relationship between the quality of the analysis and the nature of the data (i.e., categorical and continuous data). Third, the statistical investigation task provided a context for better understanding students' motivation and learning. I briefly discuss each major finding.

7.1.1 The Use of Variables: A Dichotomy Phenomenon

The evident dichotomy between those who used and/or collected categorical variables (47%) and those who used both categorical and continuous variables (53%) in the analysis is a complex phenomenon to grasp. It has been suggested that students should experience the four process components of a statistical investigation: formulating a question, collecting data, analyzing the data, and interpreting the results (Franklin & Garfield, 2006; Franklin et al., 2007). Researchers also suggest that students collect and analyze both categorical and continuous variables (MacGillivray, 2010; Neumann, et al., 2010; Quinn, 2002), while others only focus on encouraging students to analyze both types of variables (Holcomb & Spalsbury, 2005; Love, 1998; Matis, 2006). However, no study has ever examined this dichotomous phenomenon in terms of the variables that students collect and use in the analysis. In fact, there are only a few studies that examined the content analysis of students' projects (Batanero, et al., 2010; Pimenta, 2006), but in these two studies the instructors did not specifically require the students to collect both

continuous and categorical variables. Nonetheless, no study has shown that when students are given the freedom to formulate their research question and develop their survey questionnaire, not all students will collect and use both types of variables. It is possible that some students think that all surveys should have multiple choices where participants can circle their answer, as seen in Hannah's case for example. As for the analysis, it is likely that some students view categorical variables as easier to analyze than continuous variables because the students only need to show frequencies and/or bar graphs for the categorical variables. From the distinctive dichotomy observed in this study, it is reasonable to conclude that not all students would consider the opportunity to collect both types of variables because they might not realize that continuous variables are necessary in answering their research questions. It is possible, too, that they simply did not sufficiently understand the distinction between categorical and continuous variables. Some students might not even realize that they were inadvertently excluding continuous variables, and not recognize that the way they asked questions on their surveys would affect the type of data they collected.

7.1.2 Quality of the Analysis

It is important to note that out of 60 students, 47% of them adequately analyzed their data, regardless of the variables used. It is important to note that out of 60 students, 47% of them were able to adequately analyze their data, regardless of the variables used. Also, 25% of the students provided partially adequate analysis, while 28% of them were in the inadequate analysis category. This suggests that the majority of the students (72%) put in the effort necessary to complete the investigation and had the skills to do so. This suggests that majority of the students (72%) were able to analyze their data fairly well,

and that only a few students (18%) failed to put in the necessary effort and/or lacked sufficient skills to complete the project. Only a few students would need extra help to have a successful statistical investigation. Also, this shows that not all students will have a successful project, and that there might be other factors present that can influence their success (e.g., motivation, the quality of the data or survey instrument). Findings from my cross case analyses indicate that some students struggled with developing their research questions and writing the survey instrument, which then led to difficulties with the data analysis. For example, in the case of Thomas, he had overlapping categories in his survey questionnaire which made it difficult for him to analyze and interpret his results.

Furthermore, one of the major findings in this study is that the quality of the analysis is associated with the nature of data – or the use of categorical or continuous data. In other words, there is a significant relationship between the quality of the analysis and the nature of the data ($\chi^2 = 9.780, DF = 2, p = .008$). The data show that most of the students who were able to adequately analyze their data focused on collecting and analyzing categorical variables only (19 out of 28; 67.86%), while those who were not successful in analyzing their data focused on collecting and analyzing both types of variables (13 out of 17; 76.47%). In other words, the students who used only categorical variables appear to be more successful or more likely to analyze the data adequately, while a poorer quality of analysis was observed for those who used both variables. This means that the nature of the data can either support or constrain the development of students' statistical reasoning and thinking as evidenced by the quality of the analysis in the statistical investigation.

For example, Francine and Grace were able to adequately analyze their data but Francine only focused on using categorical data because her research question was on finding the number or percentage of students that are single parents in college. Francine was interested in this question because she is a single mother in college. She also put in a lot of effort in completing the statistical investigation because she was the only one in the class who piloted her survey questionnaire. The other successful student, Grace, was interested in exploring the association between grades or GPA and relationship status (being in a relationship or not). Grace was able to successfully analyze her data using both categorical and continuous variables. Both Francine and Grace were successful with their statistical investigations because they had very motivating research questions that pertained to some characteristics about their interest or identity, and they both showed high effort in completing each phase.

However, not all students were like Francine and Grace. One of the students who was not successful with the investigation was Thomas because his survey questionnaire only had categorical variables, and he had overlapping categories which made it difficult for him to interpret his results. Quinn collected both categorical and continuous variables, but she was not successful in analyzing her data because she did not show any of the required visual displays of the data, she did not include descriptive statistics in analyzing the continuous variables, and there were inconsistencies in her interpretation of the data. Both Thomas and Quinn chose generic topics, but Thomas did not collect continuous data because he thought that he had to provide the choices on the survey questionnaire, and it did not occur to him that he can obtain continuous data by asking open ended questions on a particular quantity.

A possible explanation for the students' inadequate analysis is that students who had a poor command of course concepts might have been more likely to struggle with both differentiating data types and also conducting effective analysis of the data. Another explanation for students' inadequate analysis might be due to low effort as evidenced by the limited time and effort that Thomas and Quinn expended on the investigation because both of them had full-time jobs that took time away from their studies. As it was pointed out earlier, some students used categorical variables only, which might be due to the way that they developed the survey instrument for data collection, or their perception of the difficulty of analyzing continuous variables. Overall, the discussion should not be on whether students can analyze the data adequately or not, but how students are selecting or collecting their variables. It is possible that the students who used categorical variables only in the analysis were constrained by their survey data or by their research question. Their disregard for continuous variables could also be unintentional, as was the case for Isaac and Thomas who both provided choices or categories in their survey questionnaire.

7.1.3 Motivation & Learning

Motivation. An important insight from this dissertation study is that students' motivation in completing the statistical investigation were varied and complex, based on the results from interviewing seven students. Some of the students truly enjoyed the statistical investigation, as was the case for Hannah, Francine, Grace and Isaac. Although the attainment value was slightly different for all students, it was apparent that they wanted to do well in the statistical investigation and that none of them realized that they could still pass the course without completing the project. High levels of utility value were also reported by the students because it helped them think about statistics, and the

research topic that they picked was useful to them. For example, Zach talked about the usefulness of learning more about research, while Hannah and Grace talked about taking a statistics course in the future and how this project prepare them for it. The relative cost was also different across students, with some students who struggled more than others. For example, Grace struggled with the first assignment because she proposed several questions that were qualitative in nature rather than quantitative, but she was successful throughout the remaining phases. Hannah, Francine, Isaac, Thomas and Quinn found the data analysis phases challenging, while Zach reported that this phase was relatively low cost for him in terms of time.

The goal of this dissertation study was to use qualitative methods to describe and uncover the relationship between students' motivation and statistical investigations. The study's findings in terms of motivation demonstrate that students with high values in terms of their interest, attainment, and utility (positive subjective-task values) can effectively surpass the relative cost of engaging in the statistical investigation. For example, Francine, Grace and Isaac thought that the statistical investigation was challenging, particularly the data analysis phase. They were able to overcome their challenges by asking for help from others and it appears that their strong interest in the topic carried them through. On the other hand, Thomas and Quinn struggled with the statistical investigation because of the high relative cost in terms of balancing time for studying and working full-time. It was also interesting to see that they both chose generic topics about academic choices: switching majors and time spent on studying, but these topics failed to motivate them to put in the time an effort to work on the statistical investigation. These observations underscore the complexity of understanding the impact

of relative cost in achievement related choices, and very little research has examined the ways in which students overcome the cost of engaging in academic tasks. Wigfield and colleagues (2009) noted that "despite the theoretical importance of cost to choice, to date, cost has been the least studied of the different components of subjective values" (p.58).

Furthermore, the students with positive subjective-task values also exhibited high academic effort, as indicated by the completed parts of the project, the students' progression from one assignment to the next, and revisions that they made based on the feedback. The students who showed high academic effort were more successful in their statistical investigation, as in the case of Hannah, Francine and Grace. This observation is consistent with Wigfield and Eccles' (2000) Expectancy-Value theory, which posits that students' expectancies for success and academic related choices are influenced by their subjective task values. Figure 7.1 below shows a visual summary of the students' motivation at various time points in the process of the statistical investigation, which is an extension of the conceptual framework that was discussed in the second chapter of this dissertation. The positive subjective-task values, high learning, and high effort are circled in the figure to emphasize that these are more desirable than the others (e.g., low interest, high cost). The students were listed next to the motivational constructs that I identified from the interview and discussed in the previous chapter. The arrows that point from the motivational construct to the phases of the project show the areas where the hypothesized relationship between motivation and statistical investigation happen and are made visible.

Motivation is also sustained throughout the various phases. For example, Francine's high interest in her topic can be identified from her first homework assignment. She also piloted her survey questionnaire which shows high effort. Although

she had difficulties with the third assignment, she was able to surpass it and move on to the final project. In most of the students, interest can be identified from the first phase of the investigation. This figure also shows that majority five of the seven students that were interviewed had difficulties with the data analysis phase (high cost), and that two of them (Hannah and Isaac) reported high levels of learning and utility values at the end which allowed them to overcome the high cost. Another student, Quinn, reported high cost in the data analysis phase, and she did not even submit her homework on this assignment, which shows low effort on her part. Quinn reported that time management was an issue for her because of her full-time job. In the last phase of the statistical investigation, all students reported high levels of learning and utility value. The figure also captures the students who reported low interest and low effort, which were the constructs that were not circled. In particular, Zach was classified as having low interest because he picked a topic that was easier to collect data on rather than another topic that he proposed which was related to his future career. This figure is a way to summarize the results from the qualitative data analysis. This was inspired by the expectancy-value framework by Wigfield and Eccles (2000), but instead of combining the components of the subjective task value into one area, I wanted to show the prominent constructs for the seven students based on what they said in the interview.

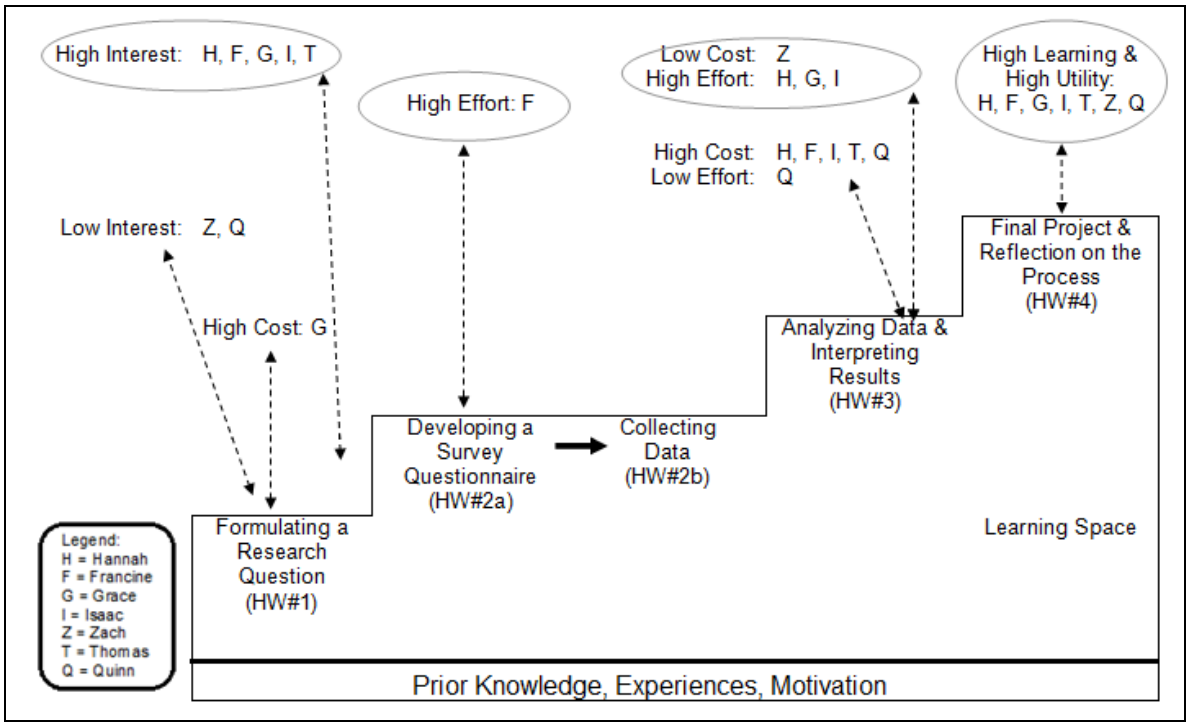


Figure 7.1: Students' Motivation & Phases of the Statistical Investigation

Learning. Quantitative analyses showed that the students exhibited significant learning gains (posttest – pretest), both from the group who completed the project (mean = 7.381 points*;* t = 14.47*;* p = .000) and those who did not (mean = 6.30 points; t = 4.81, p = .001). However, at the 5% significance level, the difference in the learning gains was not significant between groups (project versus without project). The lack of significant difference might be due to the small sample size of the group who did not complete the project (n = 10). Nonetheless, this shows that the students can learn statistics from a mathematical reasoning course. Results from the item analysis revealed that 81% of the students who took the pretest were able to correctly answer questions on calculating the mean of raw data. This shows that students entering a mathematical reasoning course (Math 1) have some basic skills in statistics.

Findings from the qualitative or case study methods described students' learning, especially in showing students' emergent statistical reasoning and thinking. Although Hannah valued the usefulness of the statistical investigation and was truly interested in her topic (baseballs and concerts), she encountered some challenges in developing the survey questionnaire and the interpretation of the results. She was able to produce the graphs and analyze her data adequately, but there were still a lot of room for improvement, especially in the interpretation of her data. The rest of the interview participants all said that they also learned the process of statistical investigation and appreciated the usefulness of the project in helping them apply the concepts that they learned in class. Thus, the statistical investigation provided an opportunity to examine students' learning with respect to statistical literacy, reasoning and thinking.

In terms of prior knowledge, it is possible that previous exposure to statistics could have contributed to the success of the students' statistical investigations. However, very little evidence suggests this because some students who claimed that they learned statistics in high school did not exhibit a depth of understanding. For example, Isaac mentioned that he took statistics in high school but the prior knowledge did not help him in applying the appropriate concepts. In fact, he was the one who calculated the standard deviation from the results in his contingency table, which shows that he had some procedural mastery but lacked conceptual understanding. Among the seven interview participants, Grace was the only one successful in analyzing both categorical and continuous data, which might be attributed to her prior knowledge of statistics.

This study has identified the benefits of engaging in the four phases of the statistical investigation, with respect to students' learning throughout the process. The

students experienced a different form of assessment, which uncovered their conceptual understanding and statistical reasoning. The feedback throughout the phases also helped the students in having a successful investigation. Although the level of sophistication of students' analyses tended to be very elementary with only descriptive statistics, the students were treated primarily as novice researchers because they had to make their own decision on topic selection, survey questionnaire construction, which variables to analyze, and in interpreting the results. In order to have a successful statistical investigation, some students would need a lot more support and feedback in order to figure out what to do with their data if they indeed had continuous and categorical data.

7.2. Implications & Recommendations

There is abundant evidence that many students benefit from a project-based learning course (Fillebrown, 1994; Lavigne and Lajoie, 2002; Nordmoe, 2007; Sovak, 2010; VanderStoep,et al., 2011). However, not all students will have a successful project, and some of them will struggle at various phases of the investigation. Although this course required them to collect both continuous and categorical data, not all students will collect and use both types of variables. The results in this dissertation study, specifically the case studies, show the *process* or how the students in this particular mathematical reasoning course were able to conduct a statistical investigation, juxtaposed with their motivation and the *final product*. This dissertation has begun to address the gap in the research on statistical investigation and motivation in the context of a math course for liberal arts students. In taking a mixed methods approach, this study has further provided evidence that students' motivation vary across the four phases of the statistical

investigation, which then interacts with the students' academic effort and overall quality of the project.

This implies that math and statistics education researchers must consider the complexity of having the students engage in statistical investigations, which can support or hinder students' emerging statistical reasoning and thinking. Although the GAISE framework was developed to encourage instructors to use statistical investigations, there are many ways that this can be enacted with varying results. Additionally, motivation is an important component and possible outcome that we need to pay attention to because of the way that it interacts with students' academic related choices (Wigfield & Eccles, 2000). For example, the Quinn had a lot of difficulties in conducting the statistical investigation, especially in the second phase where she had to construct the survey questionnaire. The difficulty of the tasks then paralyzed her instead of energizing her to complete or move from one phase to the next (Pajares, 2006). Her self-efficacy plummeted and she was not able to turn in the data analysis phase, which then resulted to a low quality final project. The challenge for researchers is to find the right balance of addressing the tension between students' motivation and the difficulties of conducting statistical investigations.

As evidence of the association between the quality of the analysis and the nature of the data shows, researchers and instructors need to pay attention to the ways in which student-generated data can limit or support the analysis. This result has important implications in helping the students develop statistical reasoning and thinking. I recommend that instructors and researchers must focus not only on the quality of students' data analysis or the *final product* of the project, but also on the nature of the

investigation or the *process*, because the types of questions and variables, the survey questionnaire that students use, and how students collect their data are all important ingredients to their successful project. For example, Isaac only collected categorical variables in his survey questionnaire on buying versus renting books, but because he wanted to calculate the mean and standard deviation of his data, he treated his contingency table as his raw data. He would have been more successful if he had included an open ended question on prices of books, for example, and then calculated the appropriate descriptive statistics.

The purpose of the statistical investigation is to help the students see the application of math and statistics using real data, and to get them interested in their research. However, student generated data, especially naïve approaches to data, can constrain the development of statistical reasoning and thinking because the quality of the data might be lacking. Isaac, Thomas and Quinn are some examples of students who had some problems with their survey questionnaire, which then resulted in a low quality data and less than adequate analysis. Although the GAISE framework is a good starting point to help instructors structure the statistical investigations, there might be other considerations that should be in place so that students can be successful in their projects. For example, instructors might need to restrict students' options in topic selection, or give them guidance in developing a research question with an appropriate level of difficulty. There are trade-offs that instructors need to consider; for instance having an assigned topic or dataset to explore might not be interesting to the student and yet it might be challenging enough for the students that learning takes place. I recommend that those

instructors who are interested in enacting statistical investigations in their courses carefully consider the following guiding questions from four major areas:

1. In formulating research questions:
    - What research questions should students formulate? (e.g., frequency, comparative, correlation)
    - Should students be allowed to pick their own topics or develop their own research questions?
    - Should instructors limit the topics by providing research questions?
    - Should instructors give a common research question to the students?
    - What types of variables should students use? (e.g., categorical variables only, continuous variables only, or both)
    - What research design do you want the students to engage in? (e.g., survey, experimental, observational)

I came to this dissertation research and designed the statistical investigation with the curiosity about students' motivation and their statistical reasoning in the context of a project. I was under the assumption that giving students complete control over the whole statistical investigation process would be motivating for them. I hoped that the students would pick topics that had such high subjective task value that each student would do a distinctive study and that they would be excited about it. This did not prove to be true. While Hannah's, Francine's and Grace's cases demonstrated this (as did the military study mentioned in chapter four) several of the students picked generic topics whose subjective task value was not as high. I recommend to instructors who are interested in enacting the statistical investigation to discourage their students to pursue these generic

topics, rather encourage them to think outside the box and choose topics that are more interesting. In addition, topics are sometimes not specific enough, and so I recommend that students write research questions instead. It might help to provide the students with a list of acceptable research questions to help inspire them to develop their own questions.

2. In collecting data:

- Do you want the students to collect their own data or use secondary data?
- If using secondary data, are the available datasets interesting to the students and appropriately challenging for them?
- What are the ways in which students can experience collecting their own data?
- Should the instructor use an existing survey questionnaire and let the students answer the questionnaire that will be used by the whole class?
- Should the instructor develop a survey questionnaire and let the students collect data amongst themselves and other students in the university?
- Do you want the students to develop their own survey questionnaire?
- What are the requirements or items that students need to have on the survey questionnaire? (e.g., categorical or continuous variables)
- What are the issues regarding the validity of the survey questionnaire?
- If conducting an observational study, are the research protocols valid and reliable?
- If conducting an experimental study, are there ethical issues with using a control group and a treatment group?

My own and my students' experiences with data collection have taught me that there is some value in this task, even though there are advantages in using large scale secondary data. I would still recommend to instructors to have their students experience some form of data collection, either in the form of a class survey or collecting observational data. Based on the results of this study, some of the students have research questions or topics that might be difficult to find good secondary data that can answer their questions. For example, Grace was interested in examining the association between grades and being on a relationship, in which there are no known large scale datasets that address this research question. Another advantage of having the students collect their own data is that they will have a richer experience in the whole statistical investigation process, as compared to those who rely on secondary data. Students will get to experience sampling, compiling their own dataset, naming their variables, and cleaning their datasets. As for writing their own survey questionnaire, it might be helpful to start with an existing survey instrument such as the Data Gather Survey (Neumann, et al., 2010), or other appropriate instruments. Personally, I would still allow my students to develop their own survey questionnaire because this is a good way to address the students' research question, which might not be available in existing instruments.

3. In analyzing the data and interpreting results:

- Do you want students to show descriptive statistics only, inferential statistics only or both?
- Are there specific analyses that students should be required to perform? (e.g., t-test, regression and correlation)

- What are the ways in which students can showcase their data analysis and interpretation of results? (e.g., poster, written report, oral report, video presentation, or a combination of these)
- What are the requirements for the written report or poster in terms of length, organization, clarity of writing, number of graphs?
- What are the ways that the instructor can give feedback to the students? (e.g., consulting setting, feedback from a rubric)
- Should the instructor give feedback before the actual submission of the final report?
- Should the instructor give feedback based on written drafts or based on students' oral presentation?
- How much feedback should instructors give to maximize students' learning potential?
- Are the rubrics clear and concise?

The first two questions above are about the requirements of the statistical investigation that instructors need to address. Findings from this study show that it is possible to conduct a statistical investigation that involves descriptive statistics only in a course for liberal arts students. Doing a statistical investigation using very simple data (i.e., categorical data) that students have collected can be sufficient in fostering statistical reasoning and thinking. However, I recommend that instructors focus on helping students understand the difference between categorical and continuous variables, so that they will be more successful in collecting and analyzing both types of variables.

In the latest iteration of my enactment of the statistical investigation in an elementary statistics course, and based on the results of this dissertation, I recommend the use of presentations (e.g., powerpoint) because having a conversation with the students makes it easier for me to give feedback on students' errors than on their written report. I still recommend having the students submit a written report on their data analysis, possibly before their presentation, which will then be finalized after the presentation. It also helps to have peer feedback so that the comments are not just coming from me. I provide handouts to students so that the ones who are not presenting can write down their evaluation of the presenters.

4. Motivation:

- How can instructors encourage students to pick topics that interest them?
- How can instructors support students' attainment value without focusing on the grades or points as a reward?
- What are the challenges or difficulties that students might encounter?
- Can the students realize the usefulness of the task?

The GAISE recommends using statistical investigation as a way of having the students engage with real data (Franklin & Garfield, 2006; Franklin et al., 2007). All students can benefit from collecting and analyzing real data, but it also depends on how the students value the task and their motivation. If the students are not heavily invested in the statistical investigation, then they will not get the full benefit of engaging with real data and making the necessary judgments in the analysis. I recommend that instructors encourage their students to engage wholeheartedly in their statistical investigations by letting the students choose topics or research questions that are challenging enough for

them while maximizing their interest and utility values. Instructors should continue to grapple with this question of the ways in which students can engage wholeheartedly in their statistical investigations.

Instructors could benefit from trying various ways of enacting statistical investigations, such as allowing the students to collect their own data, having the class collect data amongst themselves, or use appropriate secondary data. Some students might need some help in formulating their research questions – such was the case with Grace, and in developing their survey questionnaire – as in the case with Hannah and Francine. I also found that substantial feedback was important to students to ensure a successful statistical investigation.

7.3. Limitations & Future Work

Since this study only involved students in a mathematical reasoning course, and no inferential statistics were covered in this course, the analyses that the students presented in their investigations were already limited. However, every effort was made to maximize the study's potential contribution to the field of mathematics and statistics education. I developed the course materials, selected the research design, methodology and analyses so that we can better understand the relationship between motivation and statistical investigation. I attempted to craft a compelling narrative of the students to show their statistical investigations and motivations.

This dissertation is a mixed-method study that looked at the statistical investigations of 60 students, from which the seven interview participants were chosen purposively. These seven students were asked to reconstruct their experiences with respect to the statistical investigations that they completed along with their motivation.

Because this is primarily an observational study, the design prohibits a causal analysis of the relationship between motivation and statistical investigations. Consistent with qualitative methodology, the degree to which participants are representative of the population and generalization of findings was not a concern. Rather, the participants were sought to represent students with varying degrees of quality in their statistical investigations in order to describe the experiences and motivation of these students.

The conclusions that resulted from the interpretation of the qualitative data are situated within the framework of expectancy-value theory of motivation. These results may differ if other theoretical frameworks were used. I also used content analysis to examine the statistical investigations of students, in which descriptive and inferential statistics were presented. It is possible that the quantitative results may also differ if the study were to be conducted in an elementary statistics course. Further research is needed to establish the hypothesized relationship between motivation and statistical investigation.

Additionally, the small group of students who did not complete the statistical investigation is not exactly a control group, and so no comparison was made in their performance in class, except in the pretest and posttest. There is potential for future work in examining the motivation of students who chose to disengage in the statistical investigation. For example, it would be interesting to examine the relative cost that these students perceive and their reasons for not completing the project. It would also be helpful to compare the students who completed the project versus the students who do not complete it, through the use a survey instrument to measure students' motivations and attitudes, in addition to in-depth interviews.

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Appendix A - Interest Inventory – Possible Topics for Statistical Investigation

1. Do you work? ○ No ○ Yes. *Describe your job & how many hours per week?*

_____

_____

2. Describe your future career or jobs that you are planning on pursuing after you graduate.

_____

_____

3. List or describe your hobbies or recreational activities that you like to do in your free time.

_____

_____

4. List or describe your favorite sport or athletic activities that you like to do in your free time.

_____

_____

5. List the type of books, TV, movies, radio, music, or computer games that you like.

_____

_____

6. You are required to do a project in this class that will allow you to use math and statistics. Please write potential topics that you might be interested in.

_____

_____

Appendix B –Statistical Investigation Homework #1

Homework #1 – Formulate Questions

Objective: The purpose of this homework is for you to start thinking about your project for this semester. Note that this homework will be used for the next three: homework#2: *data collection,* homework#3: *data analysis & interpretation of results, and* homework#4: *final project & reflection*.

Instructions:

(1) List ***2 to 5 research questions or topics*** that you will investigate by collecting numerical data through a survey.

(2) Write a paragraph (atleast two sentences) on each of your research questions or topics, explaining the importance or benefits of answering these questions.

After completing homework#2, you will collect numerical data by conducting a survey of a sample from a larger population. This homework should be ***submitted through WebCT as a Word document attachment***, thus, it should be typewritten, single-spaced, and 1 page long.

Note: I will not approve research projects that are controversial in nature or may be offensive to the other students in class. Please consider the following in selecting a topic to help you in formulating your questions:

1. your knowledge and experience of the topic
2. your future career – *you may use this project as an opportunity to know more about the job that you'd like to apply (ex. internship, promotion)*
3. your access to the data and time constraints in data collection – *you may use survey data from your work or another project, as long as there are numerical variables in the data*
4. appropriateness of the topic and the variables – *you need to start thinking about the survey questionnaire and the variables that you will need. For example,*
    - Student A wants to keep track of her weight every hour for the next 30 hours – ***this is not appropriate*** *because this topic is trivia,l and it will not give you enough variability in the data*
    - Student B wants to ask 30 people about their weight, and if they exercise or not – *this is appropriate and can possibly yield interesting data*

You may look at some of the examples that students in previous semesters have done, available at the course webpage.

Rubrics for Homework #1 – Formulate Questions

Criteria	Need Improvement	Partially Meets Expectations	Adequately Meets Expectations
There are 2 to 5 Research Questions	Missing or no research questions were posed.	There is only 1 research question.	There are 2-5 research questions.
	(0 point)	*(1 point)*	*(2 points)*
Quality of the Research Questions	Missing or no research questions were posed.	Some of the research questions are qualitative in nature and cannot be answered by collecting numerical data. Consider revising the questions.	The research questions can be answered by collecting numerical data.
	(0 point)	*(2 points)*	*(4 points)*
Relevance of the Research Questions	The research questions are neither relevant nor important. Consider changing the topic.	The research questions are slightly relevant and important. Consider explaining who will benefit from this research project.	The research questions are relevant and important.
	(0 point)	*(2 points)*	*(4 points)*

Appendix C – Statistical Investigation Homework #2

Homework #2 – Data Collection

Objective: The purpose of this homework is for you to start thinking about how you will collect data for your research project. This homework is an important step in completing your project because the data that you will collect will be used for the next two -- homework#3: *data analysis & interpretation of results, and* homework#4: *final project & reflection*.

Instructions: Based on the feedback that you received on the previous homework, write a paragraph (or two) about what kind of data is needed and how you will collect data to answer your research questions. Be sure to include the following in explaining the data that you will collect and the process:

- ☐ Type of sampling methodology – how will you conduct the survey? (ex. random survey; polling a class)
- ☐ The feasibility of the data collection process – it should take you 2 to 5 weeks to collect the data
- ☐ Appropriateness of sample size – how many people will answer your survey? (less than 30 is not recommended since it will yield a small sample; choose 30 or more.)
- ☐ The quality and validity of the survey questionnaire – include the survey questionnaire and explain how this will help you in answering the research questions. A simple survey should have 3 to 5 questions, and should include some background information such as age, gender, or ethnicity.
- ☐ Adequacy of the variables – include both continuous and categorical variables, for example:
    1. continuous – ex. Age in years, weight, height, working hours per week, GPA
    2. categorical – ex. Age group (18-30 y.o., 31-40 y.o., 41-50 y.o., etc.), gender, Likert scales

Again, this homework should be submitted through WebCT as a Word document attachment, thus, it should be typewritten, single-spaced, and 1-2 pages long.

Helpful Hints:

- ➢ You are not allowed to collect data until I have given you the feedback from this homework. If I am not satisfied with the way that you are collecting your data, you will be allowed to resubmit this homework.
- ➢ Please proofread your survey questionnaire to avoid any errors or embarrassment.
- ➢ Again, I will not approve research projects that are controversial in nature or may be offensive to the other students in class.

You may look at some of the examples that students in previous semesters have done, available at the course webpage.

Rubrics for Homework #2 – Data Collection

Criteria	Need Improvement	Partially Meets Expectations	Adequately Meets Expectations	Exceptional
Type of Data Source	Missing or does not state the type of data source, and no description of the data collection.	Missing or does not state the type of data source; but vaguely describes the steps in data collection.	Mentions the type of data source but not the steps in data collection.	Clearly states the type of data source (e.g., random survey or poll) and the steps in data collection.
	(0 point)	*(1 point)*	*(2 points)*	*(3 points)*
Appropriateness of the Data	Failure to show that the data source is appropriate. (e.g., no sample size was mentioned)	Vaguely shows that the data source is appropriate, (e.g., the sample size is less than 30)	Fairly shows that the data source is appropriate (e.g., the sample size is close to 30)	Clearly shows that the data source is appropriate. (e.g., the sample size is 30 or more)
	(0 point) Feedback: State the sample size.	*(1 point) Feedback: Increase the sample size to 30 or more.*	*(2 points) Feedback: Increase the sample size to 30 or more.*	*(3 points)*
Quality of the Survey Questionnaire	Failure to provide a valid data source. (e.g., missing survey questionnaire; no categorical and/or continuous variables)	Poor quality of data source with inadequate variables. (e.g., the survey questionnaire needs major revisions; missing important categorical and/or continuous variables)	Vaguely shows or explains why the data source is valid, with some adequate variables. (e.g., the survey questionnaire needs minor revision; missing some important categorical or continuous variables)	Clearly shows or explains why the data source is valid in answering the research questions, with adequate variables. (e.g., the survey questionnaire is acceptable; both continuous and categorical variables are included.)
	(0 point) Feedback: Attach the survey questionnaire.	*(2 point) Feedback: Revise the questionnaire; consider other variables.*	*(3 points) Feedback: Explain clearly why the data source is valid; include both continuous and categorical variables*	*(4 points)*

Appendix D –Statistical Investigation Homework #3

Homework #3 – Data Analysis & Interpretation of Results

Objective: The purpose of this homework is for you to analyze your data and write the results of your analysis. This homework is an important step in completing your project (homework#4: *final project & reflection*).

Instructions:

1. Based on the data that you have collected, show 2 or more visual displays of data (tables, graphs, bar chart, box-and-whisker plot, etc.)
2. Write atleast one paragraph that explains or describes the visual displays of data in relation to answering your research questions. For example, you might want to compare between groups, such as male versus female groups.
3. Include descriptive statistics: mean, median, mode, standard deviation, frequencies or percentages – but make sure that you interpret what the numbers are telling with respect to the context of the study.
4. Explain possible biases inherent in the data, or limitations in the interpretation of the analysis.

Again, this homework should be submitted through WebCT as a Word document attachment, thus, it should be typewritten, single-spaced, and 2-5 pages long. All visual displays of data (tables, graphs, bar chart, box-and-whisker plot, etc.) should be embedded in the text, not on a separate file. For example, if you used Excel in making the graphs, please copy and paste it onto a Word document.

Helpful Questions:

1. What are the summary statistics from the data?
2. Do you notice any outliers in the data?
3. What do you see when you compare the summary statistics of 2 groups or variables?
4. What are the biases in the data?
5. What are the limitations?

Rubrics for Homework #3 – Data Analysis & Interpretation of Results

Criteria	Failure	Partially Meets Expectations	Adequately Meets Expectations	Exceptional
Visual Displays of Data & Explanation	Missing or does not include any visual displays of data; no graph to explain or describe.	Missing a visual display of data or the explanation is missing.	Shows 2 or more visual displays of data and an adequate description or explanation.	Shows 2 or more visual displays of data and a clear description or explanation.
	(0 point)	*(2 point)*	*(3 points)*	*(4 points)*
Quality of the Data Analysis & Interpretation	Failure to provide data analysis and interpretation (e.g., missing descriptive statistics and the interpretation)	Poor quality of data analysis and/or missing interpretation. (e.g., shows relevant descriptive statistics but does not include an interpretation)	Adequate data analysis and interpretation, with some context of the study. (e.g., shows relevant descriptive statistics but the interpretation needs revision or further clarification)	Accurate data analysis and interpretation, based on the context of the study. (e.g., shows relevant descriptive statistics and correct interpretation)
	(0 point)	*(1 point)*	*(2 points)*	*(3 points)*
Biases & Limitations	Failure to explain possible biases and limitations of the data.	Inadequate or incorrect explanation of possible biases and limitations of the data.	Vaguely explains possible biases and limitations of the data.	Clearly explains possible biases and limitations of the data.
	(0 point)	*(1 point)*	*(2 points)*	*(3 points)*

Appendix E – Statistical Investigation Homework #4

Homework #4 – Final Project & Reflection

Objective: The purpose of this homework is for you to combine your previous work (homework #1 to #3) and write a final report about your project. You will also reflect on your experience with this project.

Instructions:

1. ***Introduction***: Write an introduction to familiarize your reader about your project. Include your research questions and the relevance or importance of this research study from Homework #1.
2. ***Methods***: Write a paragraph explaining how you collected your data (from Homework #2). If you conducted a survey, include the sample size, where you collected your survey, the people who answered the survey and the variables that you included in your survey questionnaire. If you gathered your data online, tell your reader the websites (addresses), and explain why you should trust those sources.
3. ***Results and Analysis***: Based on the feedback that you received from Homework #3, explain or describe the visual displays of data in relation to answering your research questions. Interpret what the descriptive statistics are telling you with respect to the context of the study. Explain any biases inherent in the data, or limitations in the interpretation of the analysis.
4. ***Discussion & Conclusion***: *(Write atleast one paragraph)*
   - (4.1) Summarize the results of your study based on the data that you have.
   - (4.2) Explain how your results might change or remain the same if you have a larger sample or if you collect the data at another site.
   - (4.3) Comment on your level of certainty about your conclusions based on the evidence that you have.
5. ***Reflection***: *(Write atleast one paragraph)*
   - (5.1) What did you learn or like about this project.
   - (5.2) How might you change it or improve this study?

Again, this homework should be submitted through WebCT as a Word document attachment, thus, it should be typewritten, single-spaced, and approximately 3-8 pages long. If you received some feedback from the previous homework, I expect that you will make the necessary revisions for parts 1 to 3 above. Note that I will focus on grading parts 4 and 5.

Helpful Questions:

- Based on the feedback that you received on the previous homework, are there any revisions that you need to make?
- Would you get the same results if you have a larger sample or if you collect the data at another site?
- How certain are you about the conclusions that you are claiming?
- What did you learn from this project?
- What did you like about this project?
- What changes would you make to improve this study?

Rubrics for Homework #4 – Final Project & Reflection

Criteria	Failure	Partially Meets Expectations	Adequately Meets Expectations	Exceptional
Quality of Writing & Organization	Failure to submit the final project.	Missing 1 or all of the first 3 parts of the paper, and/or has numerous writing or grammatical errors.	Shows all 5 parts of the paper (intro, methods, etc.) but has few writing or grammatical errors.	Shows all 5 parts of the paper (intro, methods, etc.) and uses academic language.
	(0 point)	*(2 point)*	*(3 points)*	*(4 points)*
Quality of the Discussion & Conclusion	Failure to include a discussion and conclusion section in the paper.	Poor quality of the discussion and conclusion. (Answered only 1 out of 3)	Adequate quality of the discussion and conclusion. (Answered only 2 out of 3)	Excellent quality of the discussion and conclusion. (Answered 4.1 to 4.3)
	(0 point)	*(1 point)*	*(2 points)*	*(3 points)*
Clarity of the Reflection	Failure to include a reflection section.	Disorganized explanation of insights and/or future improvements.	Vaguely explains insights and/or future improvements.	Clearly explains new insights and future improvements.
	(0 point)	*(0 point)*	*(1 point)*	*(2 points)*
Class Presentation			Did not do an informal class presentation.	Informally presented the project in class.
	(0 point)	*(0 point)*	*(0 point)*	*(1 point)*

Appendix F – Student Interview Protocol

This research is primarily about your experience with the project that you completed in Math 1. I'm interested in knowing more about your thoughts and feelings as you went through the process of completing the four homework assignments.

Background:

1. Let me ask you about your educational background and plans after college.
   - What is your major and year in the program?
   - Tell me about your future career or jobs that you are planning on pursuing after you graduate.
2. [*To establish context*] Tell me about your experience here at sac state.
   - Do you like it here at sac state? What has been your experience with your classes? [*as a way to see if positive/negative experiences are shaping how they perceive themselves as a successful student or not*]
3. What kind of experiences have you had with Mathematics and Statistics?
   (3.1) Do you think of yourself as a "math person"? Why?
   What experiences have you had that have shaped that?
   Tell me about any math related activities in and out of school.
   Tell me a story about an experience that sticks out in mind.
   (3.2) Are you planning on taking any college math or statistics courses?
   Have you taken any math or statistics courses, aside from Math 1 in the previous semesters or years? Which math courses?
   (3.3) Based on the math courses that you've taken before, why did you enroll in Math 1 last semester?
   [*If it's a requirement*] Is there another way to fulfill that requirement?
   Do you have any particular reason for choosing this section of math 1? [*to see if the student was influenced by others who took the class previously*]

In the next set of questions, I'd like to know more about how you've experienced the statistics project or the four homework assignments.
Tell me about your experience with this project? What stands out in your mind when you did the homework assignments?
[note: the response to this question will set the conversational flow by identifying which construct was more influential to the student: attainment, intrinsic value, cost or utility]

Attainment value:

4. Last semester, you did really well in completing the statistics project. Can you tell me some of the reasons that led to your success?
   (4.1) During the first few weeks of the semester, did you think that the project would be difficult or easy? Why? How did you feel when you were given this assignment?
   (4.2) Did the project require a lot of effort or was it easy for you? Tell me about your experience in doing this task.

5. Was it important for you to do well in this project? Why?
   (5.1) What grade were you aiming for in this Math 1 class?
   (5.2) Did your goal change? How and why?
   (5.3) Did it ever cross your mind that you can still pass the class without completing this project? (If no, is it due to the grade or something else?) (If yes, what helped you in completing this project?)
6. Did you do well on similar math courses that require some kind of project? Tell me a story about your experience with other math courses similar to Math 1.

Intrinsic value:

7. About the project or the statistical investigation, you proposed several topics in Homework #1, what motivated or influenced you to pick this topic in Homework #2? [note: point at Homework #1 and #2]
8. Why did you choose to do this project?
9. Did you enjoy working on this project? (follow-up: Was this interesting or boring? Anything that you liked about the project? Disliked about the project?)

Cost:

10. Tell me about the data collection, how much time did you spend on it?
    (10.1) Why did you choose to put in that much time on it? Did it seem like a lot of time?
    (10.2) What about the rest of the project? How much time did you spend on the data analysis [note: point at Homework #3 and #4]
    (10.3) Did you think that the amount of effort was worthwhile to you?
11. Did you experience any setbacks or challenges in completing this project? How did you deal with those setbacks?

Utility value:

12. Some students say that these projects are just "busy work" while other find it very useful/important, where do you see yourself in this continuum? Why?
13. Learning about math and/or statistics:
    (13.1) What kind of math or statistics did you do? Was that new to you? Did you learn any math or statistics from doing this project? Was the statistical investigation helpful to your learning or not? Why?
    (13.2) Do you see yourself doing something similar to this project in the future or in your other classes? How useful is this activity for what you want to do in the future?
    (13.3) Did this project change the way you used to think about math and statistics? How so? Tell me about how you though about statistics before and after doing the project.
14. Which part of the project or homework did you find helpful or useful? Why? [note: show all 4 Homework to activate stored memory]
15. How did you feel after completing the project?

Reflection Question:

16. Do you think that I should continue requiring the students to do this project in a Math 1 class? Why?
17. Do you have any suggestions or comments about doing this project or activity? What would you advise current Math 1 students about doing this project or activity?
18. Anything else that you'd like to add or mention about your experience with the project or the statistical investigations that we haven't covered?

Appendix G – Pre & Post Test: Basic Statistics Exam

Basic Statistics Exam – Multiple Choice (Pre-test)

Directions:

1. Do not write anything on this test questionnaire. Please use the blank pages provided in class for any additional calculations.
2. Shade your chosen answer on your scantron sheet.

Note: ***Your grade will not be affected by taking this exam,*** since this is only a diagnostic tool in assessing your knowledge of statistics and readiness in conducting the project.

MULTIPLE CHOICE. Choose the one alternative that best completes the statement or answers the question.

Find the mean of the set of data.

1) 11.88, 13.12, 15.34, 7.87, 5.27, 3.56, 17.16, 7.11 1) _____
Round your answer to two decimal places.
A) 9.03 B) 7.13 C) 9.49 D) 10.16

Find the median.

2) 2) _____
3.5 1.6 2.4 3.7 4.1
3.9 1.0 3.6 4.2 3.4
3.7 2.2 1.5 4.2 3.4
2.7 0.4 3.7 2.0 3.6
A) 3.40 B) 3.45 C) 2.94 D) 3.50

Find the mode or modes.

3) The weights (in ounces) of 14 different apples are shown below. 3) _____

5.0 5.5 4.6 6.9 4.1 5.0 5.5
5.7 6.0 6.9 5.0 4.8 6.9 4.4
A) None B) 5.0 C) 5.0, 6.9 D) 5.5, 6.9

Find the mean for the given frequency distribution.

4) 4) _____

Value	Frequency
123	1
191	4
244	5
318	2
324	3
382	2

A) 298.6 B) 93.1 C) 263.5 D) 244.3

Find the median for the given frequency distribution.

5)

Value	Frequency
20	4
30	6
40	5
50	3
80	1

5) _____

A) 30 B) 35 C) 40 D) 44

MATH 1 — BASIC STATISTICS EXAM (Pre-test)

Find the mean for the given sample data. Unless otherwise specified, round your answer to one more decimal place than that used for the observations.

6) The grocery expenses for six families were $77.09, $76.90, $53.00, $65.69, $51.95, and $84.23. Compute the mean grocery bill. Round your answer to the nearest cent. 6) _____

A) $68.14 B) $69.77 C) $102.22 D) $81.77

Find the mode or modes.

7) Last year, nine employees of an electronics company retired. Their ages at retirement are listed below. Find the mode(s). 7) _____

57 61 65
56 52 64
68 58 53

A) 58 B) 57, 61, 65, 56, 52, 64, 68, 58, 53
C) 59.3 D) No mode

Solve the problem.

8) To get a C in history, Caroline must average 74 on four tests. Scores on the first three tests were 69, 77, and 63. What is the lowest score that Caroline can get on the last test and still receive a C? 8) _____

A) 13 B) 87 C) 71 D) 70

Find the range for the set of data given.

9) 9) _____

Value	Frequency
13	2
21	5
25	4
28	3
36	3

A) 22 B) 24 C) 23 D) 49

10) 0.172 0.114 0.518 0.369 0.619 0.29 10) _____

A) 0.118 B) 0.114 C) 0.505 D) 0.518

Solve the problem.

11) A radio station claims that the amount of advertising per hour of broadcast time has an average of 13 minutes and a standard deviation equal to 2.6 minutes. You listen to the radio station for 1 hour, at a randomly selected time, and carefully observe that the amount of advertising time is equal to 7 minutes. Calculate the z-score for this amount of advertising time. 11) _____

A) -15.6 B) 2.31 C) -2.31 D) 0.34

12) Martin scored 40 points on a quiz. The average score for his class was 39 with a standard deviation of 2.4. Martin's brother Jeff who is in a different class also had a quiz. He scored 29. The average score in Jeff's class was 26 with a standard deviation of 1.9. Find the z-score for each person. Relatively speaking, who did better? 12) _____

A) 1.0, 3.0, Jeff B) 0.42, 1.58, Jeff
C) 1.0, 3.0, Martin D) 0.42, 1.58, Martin

MATH 1 — BASIC STATISTICS EXAM (Pre-test)

Rank the data from lowest to highest and determine the requested quartile.

13) The following scores on the midterm exam in Chemistry 102 were recorded. 13) _____

93 81 59 69 82 75 61 77 95 84 88 71
86 97 63 72 89 80 60 98 91 62 78 83
76 81 94 66 83 96

Find the 3rd quartile, Q_3.

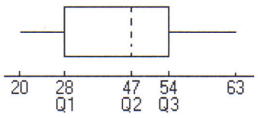
A) 77 B) 89 C) 86 D) 88

Solve.

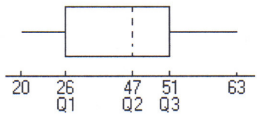
14) Construct a box plot from the data below. 14) _____

20 25 26 26 26
27 29 33 41 43
45 46 47 48 50
50 50 51 53 55
57 60 61 62 63

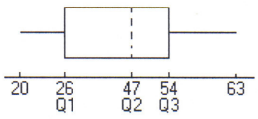
A)



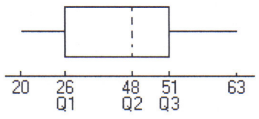
B)



C)



D)



Use the regression line to predict the value of y.

15) Eight pairs of data yield the regression equation $y' = 55.8 + 2.79x$. What is the best predicted value of y for $x = 2$? 15) _____

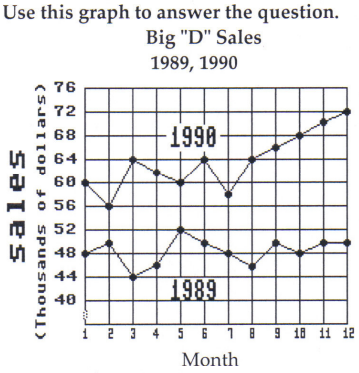
A) 71.125 B) 114.4 C) 61.4 D) 57.8

16) The regression equation relating attitude rating (x) and job performance rating (y) for the employees of a company is $y' = 11.7 + 1.02x$. Ten pairs of data were used to obtain the equation. What is the predicted job performance rating for a person whose attitude rating is 57? 16) _____

A) 12.6 B) 68.9 C) 80.1 D) 69.8

MATH 1 — BASIC STATISTICS EXAM (Pre-test)

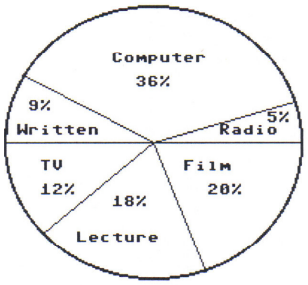
Use this graph to answer the question.



17) What month in 1990 had the lowest sales? 17) _____

A) Month 5 B) Month 12 C) Month 2 D) Month 3

In a school survey, students showed these preferences for instructional materials. Answer the question.



18) About how many students would you expect to prefer written materials in a school of 650 students? 18) _____

A) About 59 students B) About 117 students

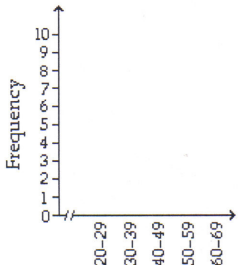
C) About 9 students D) About 234 students

Construct the specified histogram.

19) The ages of the voters at a poll during a 20-minute period are listed below. Use five classes with a uniform width of 10 years, where the lower limit of the first class is 20 years. 19) _____

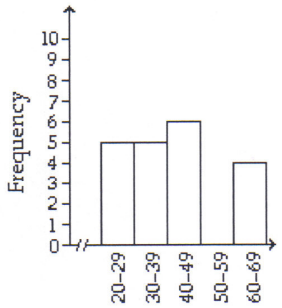
35 29 48 63 64 38 21 23 41 68

61 42 43 47 33 37 46 27 23 30

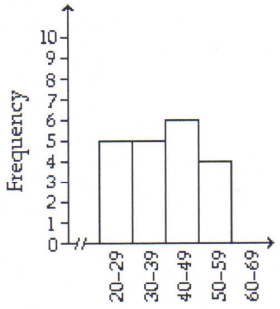


MATH 1 — BASIC STATISTICS EXAM (Pre-test)

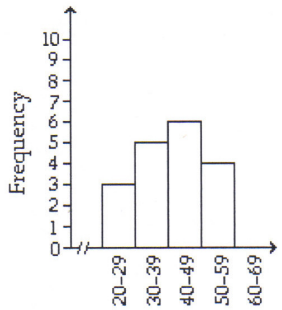
A)



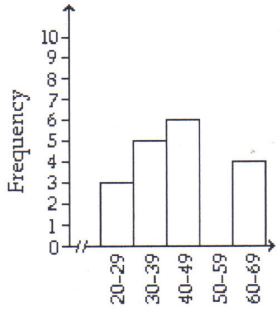
B)



C)



D)



Construct a stem and leaf display for given data.

20) Here are the final scores for the last 16 games played by the local basketball team. 20)

45 54 53 65
67 75 57 59
87 86 79 74
67 75 87 65

A)

4	45
5	53 54 57 59
6	65 67
7	74 75 79
8	86 87

B)

4	5
5	3 4 7 9
6	5 5 7 7
7	4 5 5 9
8	6 7 7

C)

4	45
5	53 54 57 59
6	65 65 67 67
7	74 75 75 79
8	86 86 87

D)

4	5
5	3 4 7 9
6	5 7
7	4 5 9
8	6 7

Answer Key:

1. D	6. A	11. C	16. D
2. B	7. D	12. B	17. C
3. C	8. B	13. B	18. A
4. C	9. C	14. A	19. A
5. A	10. C	15. C	20. B