Title of the submission
The Meaning of ‘Mean’: Teacher perception of student understanding within a college statistics course

Name of the author
Steven Tuckey

Affiliation of the author
Michigan State University College of Education, Department of Teacher Education

Address of the author
301D Erickson Hall
Michigan State University
East Lansing, Michigan 48824

E-mail address of the author
tuckeys1@msu.edu

Abstract of paper
The role of ‘understanding,’ and the multi-contextual nature of the term itself, is a topic of both great interest and debate within the mathematical and statistical education communities. Reform programs and entire movements compete for attention and funding by implicitly comparing theoretical frameworks that define understanding in many ways. Whether or not a conceptual/procedural dichotomy is presumed, the way in which students and teachers ‘understand’ topics in mathematics and statistics continues to require investigation and, hopefully, improvement. Every researcher within these domains must be wary of their own treatment of understanding; yet, care must also be taken with the implicit assumptions of teachers who help shape the ways in which students come to their own understanding(s). The main purpose of this pilot study is to examine the relationship between students’ understanding of the concept of arithmetic mean, and that of their current statistics instructor. By comparing the results of a student survey with the instructor’s conceptions of both student understanding and beliefs about mathematical/statistical understanding in general – thus allowing the instructor’s own framework for understanding to be the basis for measuring student understanding – I hope to shed light on the complexities of understanding-oriented research and to contribute to the larger field of statistics education research. Results indicate that a question about student beliefs turned into an assessment of statistical understanding in the eyes of the instructor. Furthermore, the difference between the time of the data collection and the time at which the mean concept was taught became critically important in the analysis of student understanding. Both of these revelations would have remained undetected, had the standard student-based questionnaire been the sole source of data.
Background

The Problem

There are many concepts in statistics that have far-reaching and multi-disciplinary impacts – perhaps one of the most important is that of the “arithmetic mean” (hereafter referred to simply as “mean”). Certainly, many statistics education researchers have investigated the development of the mean concept in a variety of ways within the discipline (Pollatsek et al., 1981; Hardiman et al., 1984; Graham, 1987; Rubin & Rosebery, 1990; Well et al., 1990; Batanero et al., 1994; Gal, 1995; Mokros & Russell, 1995; Noss et al., 1999). Yet, how a student comes to understand this concept and how he or she is able to communicate that understanding is likely to have effects on the ways in which they approach topics as far-ranging as scientific inquiry and political argumentation, both of which are intimately related to populations and sets of data. If a student, say, comes to perceive the mean of a data set as an actual physical representation rather than a meta-representative of the set, they may develop beliefs about normalcy and aberration that are both inflexible and dangerous (Rose, 1989). Such a student may come to believe that all carbon atoms have a mass of 12 AMUs or that all employees of a corporation have highly similar salaries, both of which could possibly limit their ability to expand upon prior knowledge or promote socioeconomic misconceptions. The ‘danger’ here lies in the possible abuses and misuses of this concept that may be undetectable to an individual with naive conceptions of mean.

This growing danger has been discussed many times before, and through many different lenses. Mathematicians like John Allen Paulos have argued that the population of this country is facing a crisis of “innumeracy,” or the “inability to deal comfortably with the fundamental notions of number and chance” (1988). In Paulos’ eyes, we are educating generations of individuals who are not able to reason in a democracy or function as critically minded adults. Yet, it is not only those within the academy who are worried. Activist and scholar Robert Moses has campaigned for the treatment of mathematics and statistics education as a fundamental civil rights issue (2001). His work with urban, minority students shows that quantitative subjects are like any languages taught in an indirect fashion that favor the culture of power by virtue of having their rules blurred.

Discussions of equity typically have focused on access to subject matter, as if subject matter were a neutral thing. The contributions of authors like Tom Popkewitz (2002), Bruno Latour (1986) and Steve Woolgar (1986) to this discussion show that subject matter, whatever it might be, is not norm-free, and therefore can be exclusionary. For example, the disparity between a ‘dumbed-down’ and rigorous curriculum can have drastic effects on student learning, achievement and equity. Moreover, the question of what counts as subject matter (and who gets to say) has only recently entered into the larger conversation. Therefore, issues of power, normalization and equity are necessarily woven into any discussion of mathematical or statistical understanding. The addition of such complexity could easily be viewed as disheartening, yet it clearly falls on the research community’s shoulders to keep this dialogue and inquiry open while also finding ways to deal with the empirical morass that is education. The issues are too fundamental and the stakes too high to ignore.
Framework for Understanding

Any discussion of understanding is likely to engender arched brows and skeptical interpretations. Quite often, authors are either unaware or unforthcoming with their theoretical framework for what qualifies as understanding. In this paper, I choose to treat understanding as a fluid, cyclic pattern of growth – borrowing heavily from Pirie and Kieren’s recursive model and Sfard’s use of process, object, and reification.

The Pirie and Kieren (1989; 1992; 1994a; 1994b) model for understanding is supported by evidence from several case studies of students at multiple (content and age) levels. From Richard, the college student, to Sandy, the inquisitive youngster, the idea of a recursive and transcending notion of understanding is both valid and valuable. One thing that certainly sets Pirie and Kieren’s theory apart from those of previous researchers is the lack of presumption about what goes on within the students’ heads. Quite clearly, Pirie and Kieren state that understanding is not a realm for truly objective classification into categories, but a necessarily spiraling mapping of actions that are inherently dependent upon both the observed and the observer. Pirie and Kieren assert that “analysis can only ever be based on what the teacher observes” (1994b, p.182). It is precisely this point that is at the heart of the present analysis.

In developing a new take on old questions of knowing and understanding, Anna Sfard (1991) creates more terminology while also serving to marry the previous (and arguably unnecessary) segregation of ideas related to instrumental/algorithmic/procedural and relational/abstract/conceptual understanding. Claiming that “abstract notions, such as number or function, can be conceived in two fundamentally different ways: structurally – as objects, and operationally – as processes” (p.1). She goes on to define these internal and subjective ways of conceiving these notions (concepts). Structural conceptions treat mathematical notions as if they referred to some abstract objects, and are static, instantaneous, and integrative. Operational conceptions tend to operate around processes, algorithms and actions rather than objects, and are typically dynamic, sequential and detailed. While structural conceptions are those that are supported by visual imagery, operational conceptions are informed by verbal and narrative representations.

Unlike many previous theories around segregated understandings, Sfard does something quite elegant. Though she recognizes that “there is a deep ontological gap between operational and structural conceptions” (p. 4), she creates a model for implementing these two types of conceptions that guarantees they are, in fact, complementary and as necessary in the learning process as both left and right feet within the walking process.

By combining operational and structural conceptions into a tightly woven mesh in which operational necessarily comes before structural, it appears that Sfard has even considered the holes in the argument – her rhetoric is well crafted to cut off any dissent as it arises. By developing an historical account for the operational-first development of the concept of numbers, the author begins to make a case for the same feature in her model of implementing understanding. Realizing that some (see Rittle-Johnson & Siegler, 1998) may suggest examples where students apparently develop what she might call structural conceptions first, Sfard counters that “this stage, which is clearly a deviation from our scheme, may be transitory or permanent” (p.21). In effect, pushing any deviant examples into the questionable periphery, she goes on to dismiss any serious challenges saying that
structural conceptions may come first “in the case of professional mathematicians – their well-trained minds can indeed be capable of manipulating abstract objects right away, without the mediation of computational processes” (p.22). Clearly, students in an introductory statistics class do not fall into this category, so it appears silly to argue against it. And, in the case that any research would be carried out to show how structural presentation of material could be done, Sfard’s argument for this model’s iterative process presents a “prevailing tendency” of operational conception before structural conception, since “even if a new concept is introduced structurally, the student would initially interpret the definition in an operational way” (p.23).

The model for understanding growth that Sfard proposes has some excellent features of previous authors’ works. It is iterative in the sense that it is cyclic and self-referential – similar in some respects to the ideas proposed by Pirie and Kieren in regards to their notion of “folding back.” At the same time, the theory has a more simplified and regular pattern to it than that of Pirie and Kieren – this reduced level of complexity is sure to make any first-time reader much more comfortable. The theory is also interested in the internal machinations of understanding, but allows for the fact that we must “describe each phase in the formation of abstract objects in terms of such external characteristics as student’s behaviors, attitudes, and skills” (Sfard, 1991, p.18). This honesty about the observed nature of understanding is further buttressed by the authors claim that the reader should rightly be skeptical of any “model of concept acquisition,” due to their “highly speculative character” (p.21). Yet suggesting that “it has already started to prove itself useful as a tool for planning, integrating, and interpreting empirical research” (p.21), this model must be taken quite seriously as well.

**The Role of the Teacher**

So, the way in which a statistics student comes to understand the mean as a process or object is a complex progression, as most students are exposed to the concept prior to engaging in a dedicated statistics course. The role of previous treatments of the concept notwithstanding (though still highly relevant, depending on the students’ experiential backgrounds), how the teacher of such a course addresses the concept of mean in their teaching is also a critical factor. Yet, one cannot easily separate the ways in which a teacher teaches a concept from the ways in which they think about the concept – and their vision of what student understanding resembles. If a teacher is limited by subject matter knowledge or pedagogical content knowledge (PCK), regardless of the scope of such terms, the results of their engagement with students in the subject area is likely to be negatively impacted (Shulman, 1986).

Though not speaking to statistics directly, Deborah Ball explains that we need to help teachers “move toward the kinds of mathematical understanding needed in order to teach mathematics well” (1990, p.143). This implies that PCK is an extant type of understanding – one that exists outside the realm of teaching (which may explain why there are ‘good’ teachers in atypical, non-teaching fields). This might mean trouble since teaching can not claim any actual realm of knowledge as its own (statistics is not for/by teachers), and this statement therefore implies an admittance of PCK as yet another realm of knowledge of which we in education are merely purveyors. This confusing fact of life for educators – like a disciplinary identity crisis – is a topic that requires some analysis.
As a result of the stagnation and mutation of academic subjects within educational systems (as compared to their “real life” counterparts), and due to the somewhat fuzzy focus on applied teacher education research (centered on the “soul” of those involved in the educative process), Popkewitz (2002) suggests that—similar to earlier dreams of alchemists—academic subjects, as taught in schools and colleges, are a transmogrification of their true disciplinary selves.

This is a powerful statement—sure to raise the ire of many, and not just in one camp. Teachers could easily interpret the argument as a critique of their roles (i.e., a statistics teacher is not really a Statistician) given that school/college subjects are simply “place marker[s] for governing the [student’s] psychological development and growth” (Popkewitz, 2002, p.264). Furthermore, Popkewitz confronts the components of the educational system concerned with discipline (which also necessarily involves teachers) in claiming “the evidence of teaching school subjects, pedagogical content knowledge, and curriculum standards are about the psychological well-being or the deviancy of the child” (p.265). Some educational researchers are also likely to squirm when faced with his observation that “policy and research cannot leave practice or experience as unmediated reality” (p.267). In effect, the actual evidence that we should be basing reform and policy decisions on is refracted by the strange theoretical medium through which observations are made. The only way for this refraction to be lessened seems to be involving the interpretations and qualifications of those within the medium of teaching—and accepting the difficulties that come along with such interpretations.

Therefore, since understanding is a phenomenon that can only be observed by those intimately familiar with both the material and the teaching-learning environment through externalized ‘performances,’ it is clear that any study of students’ statistical understanding requires several characteristics. The following section describes a study that focuses on student understanding of the mean concept (as defined by the instructor) and its relationship to the attitudes and beliefs held by both instructor and students.

**Methodology and Research Design**

The focus of this pilot study is to examine the role of teachers’ definitions of “understanding” on their students’ conceptions of the mean. Specifically, a statistics course at a junior college in a small mid-western city was examined. Students in the course ranged from 20 to 50 years of age (with a majority in their late 20s), and the college admissions data show students to be from lower-middle to middle class, socioeconomic backgrounds, and all participants are white. The instructor has taught statistics and mathematics at both secondary and post-secondary levels for nine years, and received secondary certification and an advanced degree in applied mathematics from a major university in the area. The course is designed to transfer as introductory statistics and probability credits for nearby state universities, and is organized and overseen by the instructor (who teaches multiple sections of the course every semester). The topics covered are typical for an introductory course in the subject matter (see Appendix A), with the mean concept (along with other measures of central tendency) being one of the earliest topics of explicit instruction.
Students were given a survey (see Appendix B) by the course instructor near the end of the semester (ten weeks after the concept of mean was initially addressed) at the beginning of a class session. It was presented to all students \((n = 20)\) as an anonymous (and therefore non-graded) survey designed to help the instructor assess student understanding, and thereby, her own teaching of a particular topic. The survey asked students to respond to two items, allowing space for free-response. The first item was an affective qualifier – “please describe what you see as the ‘purpose’ of statistics” – designed to elicit student beliefs about the nature of statistics. The second question asked them to explain what is implied by “mean.” The form allowed for adequate writing space, asked for open and complete responses, and was collected after ten minutes of allotted writing time – by which point all students were finished – and all responses were gathered together. No discussion of the items was entertained during or after the response time, though some students did linger after class to converse with the instructor about its contents.

After collecting the responses, the instructor was then asked to analyze them, one question at a time, and evaluate the responses. For the first question, she was asked to rank the responses to the item on the basis of how well it matched her own. A Likert scale was used to rate each student’s response, relative to her own beliefs about statistics. For the second question, the instructor was asked to assess the depth of each response in terms of “a clear display of understanding the concept of mean.” The instructor ranked the responses for this question on a 4-point scale for understanding, similar to that of Cai (2000), as follows: To receive a score of 4, a student’s explanation must show a correct and complete understanding of the topic. At the score level 3, students’ explanations would basically be correct and complete, except for a minor error, omission, or ambiguity. To receive a score of 2, the explanation should show some understanding of the topic but would otherwise be incomplete. If a student’s explanation shows limited understanding of the topic, it would be scored as 1. If a student’s explanation shows no understanding of the topic, the response would receive a score of 0.

Once the data were organized and analyzed, the instructor was briefly interviewed to enhance the view of her beliefs and impressions of student understanding. This interview took place in an informal setting where responses were noted and further clarification was pursued.

**Results and Discussion**

Quantitative results for both items are summarized in Appendix C.

**Item 1**

The responses to the first item were rated on a Likert scale by the instructor (1 being the lowest and 5 being the highest) in terms of how well they matched her own response about the purpose of statistics. There were three 5s, five 4s, nine 3s, two 2s, and only one 1. This rating was done prior to the interview, but showed signs of being an iterative process (original ratings were crossed out and new markings placed below, sometimes more than once). During the interview, the instructor was asked for general criteria that she used to distinguish between the levels. Her scale was given as follows:
The 1s were those who either didn’t take the item “seriously, or were clueless” about statistics. The 2s “grasped that [statistics] is all around, but don’t know much else” about it. The 3s were “either people who have a minimal understanding of hypothesis testing (to prove something right or wrong),” or who focused solely on how statistics is personally relevant to them or their careers. This was the largest grouping, and the instructor suggested they were all “good ideas,” but not “filled out.” The 4s discussed hypothesis testing, but didn’t “put it with description, only inferential.” The 5s – not the smallest group, by far – successfully “combined hypothesis testing with other, descriptive, aspects” of statistics. It is interesting to note that the most highly rated answers all contained specific topics most recently discussed in the course, as identified by the instructor. This may suggest that the instructor’s views on the purpose of statistics are directly related to the current curriculum that is being taught.

When asked to provide an answer for the first question (only after all student responses had been codified and discussed), the instructor immediately provided one. Her answer implied that statistics “has two main important purposes: to analyze data and infer from that data.” She went on to suggest that the “tool for inference is probability, possibly its own subject and the handmaiden of stats.” Lastly, she obliquely addressed issues of governance and equity in suggesting that statistics allows people to “describe what is going on and make decisions and judgments about it.” At one point in the interview, the instructor commented on the vagueness of the first item, saying that it was highly “dependent on who’s answering” the question – showing an awareness of the contextual nature of the assessment. She also implied that students’ responses to this item were not likely representations of what they actually thought – both, due to their brevity and her belief that students “just don’t realize” how often statistics are used in their lives.

Although not conclusive from the data represented here, yet certainly compelling is this notion of the ‘purpose’ for a given subject. That is, for this instructor and these students, how would any of them define the ‘purpose’ of statistics at any given point in the semester? For instance, a reply that earned a rating of 3 at the time of this survey may have earned a rating of 5 at the beginning of the semester – since it showed a depth of awareness not elicited by the course material. On the other hand, this same response at the end of the semester would likely have garnered a much lower score, due to its apparent lack of depth. This reasonable disparity, though not captured in the text of any given response, speaks to the variation in discursive context surrounding statistical terminology at different points in the semester. To put it another way, an acceptable belief about the purpose for statistics on day one of a course is not the same as what passes muster on the final day. The discourse changes – whether or not this change is made explicit by the instructor or a student is another matter.

**Item 2**

According to a study performed by Cai (1998), students who solved averaging (arithmetic mean) problems more abstractly tended to have more correct solutions – which may “suggest that students’ use of algebraic and arithmetic representations reflect their conceptual understanding of the algorithm” (p.96). This corresponds to the understanding that Nesher (1986) refers to in the sense that the act of practicing the use of algorithms, and hitting stumbling blocks along the way, can often afford a deeper
understanding of a concept. This focus on the algorithmic nature of the mean seems to be the case for the students within this study.

Though they were not asked to solve a problem, every one of the twenty students responded to the second question by creating a sample data set upon which to show/define (through the process of calculating) the mean. Seven students chose to draw a graph, chart, or diagram to illustrate their data set (representing specific sets of quantities like test scores, days, or pounds), while the thirteen others used textual examples such as the following: “If I were to take all my test scores for this class…;” “It’s like looking at a baseball player who goes to bat ten times in a game…” It is interesting to note that only one student involved any connection with the probability curriculum (related to coin tosses), while several (five) related their examples to the most recent topic of hypothesis testing.

In discussion with the instructor, she clearly was impressed that students were able to come up with a wide array of examples, though she commented on the similarity between many of the examples used and those she offered as part of class instruction. She noted that following the ranking rubric (0 to 4, low to high understanding) was difficult, as the cut-offs between levels are ill-defined. Though there were only two student responses to this item that were deemed worthy of a 1 (and none that qualified as a 0) by the instructor, every student seems to perceive the mean as “something that you do” (to quote a student response) to a data set. Only one student response was given an understanding rating of 4, and the remaining seventeen were given 3s. The instructor explained that the top scoring response “really wasn’t perfect, but I could tell that [the student] really understood.” When pressed to further clarify this distinction, the instructor implied that many of the abstract pieces were present, even if they had not been completely put together. Given this information, it seems reasonable to conclude that (according to the instructor) this student was perhaps on the brink of what Sfard (1991) refers to as “reifying” the process of ‘mean’ into an object. All of the responses that garnered a score of 3 seemed to suggest explanations that lack enough evidence to show proximity to this process-object tipping point. Furthermore, though she was surprised that no student included a more abstract definition, she had several things to say about the survey that help place the results within a context.

The instructor noted quickly that the survey did not specify arithmetic mean, but suggested that it “is implied whenever the term ‘mean’ is used alone.” Regardless of the veracity of this statement, it shows a perceived comfort with the discourse of the subject. Further exemplifying this comfort was her response to the second item, which was not asked for until all student responses had been discussed. She explained that the arithmetic mean is “one of the major measures of central tendency” and that it “has many aspects,” including ideas like “non-resistant,” “a balance point on a graphical display,” and “includes all data values.” Finally, she settled on a succinct definition that she felt would have been acceptable from any student: “The mean is the best non-resistant measure of central tendency.” When asked about the necessity of an example, or sample set upon which to show the process of mean calculation, she simply said it did not “get to the concept” and was not critical to show understanding on this task at that point in the semester.

This brought up another item of discussion – did the point in the semester at which the survey was given reflect in their answers? To some degree, since the mean
concept was discussed earlier in the semester, timing did matter. According to the instructor, students “really just learn to compute it, since that is all they get to do with mean since the second day” of the course. As one of the earliest concepts taught in the course, mean is not something that was recently discussed in a formalized, abstract way. Instead, it is an idea that occurs “in every one of the six chapters we’ve covered” since the time it was originally discussed. According to her, the students have experienced the abstract nature of the mean, and are now employing it in different ways. Therefore, it may be tempting to suggest that they are doing what Pirie and Kierin (1989) would refer to as “folding back,” given the new contexts in which they find their understanding being challenged. Yet, the instructor clearly believes that students see the mean as a process solely because of the extensively process-oriented nature by which it is treated throughout the course – thereby suggesting that, in applying Sfard’s model, reification can be delayed, or even prevented by curricular and instructional decisions. To be sure, the prevalence of calculation in student responses seems to suggest exactly that.

General Comments

Though students tended to have similar beliefs about the purpose of statistics, they appeared to overwhelmingly agree on the nature of the mean concept. However, when taking the context of the instructor’s comments into consideration, the situation changes. While the instructor felt empathetic toward student understanding of the mean concept, and even gave ‘top marks’ to a student whose understanding was admittedly incomplete, she hoped for and suggested the promise of future growth. Furthermore, the distinction between “compared to your answer” and “given that your answer is correct” seemed not to be made in her analysis of the first item’s responses. Using terms like “clueless” and relying on specific course content rather than a comparison are two clear signs that a question about beliefs turned into an assessment of understanding in the eyes of the instructor. It is crucial to note that neither of these revelations would have been detected, had the interview not taken place.

Significance and Conclusion

Clearly, there are important issues surrounding this study that deserve attention. First of all, the nature of the survey, being highly dependent upon literacy (both linguistic and statistical), suggests the possibility of overlap between interpretation of difficulty in one area with contamination from another. Though this could likely not be eliminated, it could be controlled for by either providing more time (these students seemed not to require it) or developing additional measures that could compensate for writing inabilities. Measures of this nature have already been explored by Lee and Fradd (1996), who used picture cards to elicit responses from second-language learners – though at some cost, both literally, in terms of resources, and figuratively, in terms of interpretation. Given the scale of this pilot study, this measure seems intensive, at best. Given the responses and the time required to generate them, it seems highly likely that students had more of a problem dealing with their desire to answer than they did with their ability to answer the items.
Another consideration, and one which could be certainly explored in a larger-scale study, is that of sample size. Given that the real unit of analysis for this study is the instructor-class set, it seems at first specious to draw any sweeping conclusions from the data. In fact, aside from pointing out the necessarily ultra-contextual nature of research into understanding, and its dependency on everything from the teachers and students to the assessment device and curricular point at which it is employed, this study does not seek to make any general or unsupportable claims. A follow-up study of broader scale (with multiple teacher-class units, perhaps at multiple educational levels) would certainly generate enough data to warrant specific claims.

One might also take issue with the survey tool itself – and understandably so. This tool was designed as an open-ended, small scale measure that could provide some data on student beliefs (about statistics) and understanding (of the mean concept) that would not be overwhelming for a single researcher operating within multiple time and budgetary constraints. Yet, it does not directly ask respondents for mere display of rote knowledge – in fact, statistics educators have shied away from the assessment of purely factual knowledge for some time (Jolliffe, 1997). Instead, it provides an open opportunity for students to display whatever level/amount/kind of understanding they feel is most central to the topic (and, arguably, that they possess). Again, discursive roles come in to play, in that the language students choose to employ when describing statistics’ purposes or mean concept should be sophisticated enough to accurately represent their ‘understanding.’ In this manner, I hoped the survey results would provide the instructor with the students’ own versions of the purpose of statistics and the mean concept, so as to determine how these would compare with hers. Granted, this device requires adjusting – more so now that it has been tested – but it stands up well as a means for collecting the simple data for which it was designed. Moreover, it points to the ways in which the discourse surrounding statistical terminology is shaped, and refined, and – in some cases – ignored over the span of a course, and how that might influence both the community within the classroom and students’ access to the larger discourse surrounding statistics.

As they emerged from the analysis of student and instructor responses, the similarities and differences seemed to support the larger notion of understanding as contextual and therefore necessarily something that requires instructor-level interpretation. The instructor in this study managed to shed enormous amounts of light on the nature of student responses, the growth of student understanding as it supports a process-object or recursive model, and the specific contexts in which the students and the topics on the survey were situated.

If one lesson is to be learned from this, it is the importance of accepting the instabilities associated with educational contexts, and the uses of teacher-clarification as a means for minimizing the refractive power of the medium researchers find themselves in when gathering data. By ignoring the symbiotic nature of student understanding, the discursive community of statistics, and teacher perception of both, researchers can not achieve a robust and thorough perspective on the ways in which students come to learn statistics. Looking at student responses in conjunction with (and especially after) their teacher has, and finding out what teachers think about the responses within their own class contexts, is critical for gaining a more complete picture of the growth of statistical ‘understanding.’
Appendix A – Topics Covered (in Chronological Order) According to Instructor’s Course Syllabus

Introduction to the Practice of Statistics
Observational Studies
Simple Random and Other Types of Sampling
Sources of Error in Sampling
The Design of Experiments
Organizing Qualitative Data
Graphical Misrepresentations of Data
Measures of Central Tendency
Measures of Dispersion
Grouped Data
Measures of Position
The Five-Number Summary
Boxplots
Scatter Diagrams
Linear Correlation
Least-squares Regression
Diagnostics on the Least-squares Regression Line
Nonlinear Regression: Transformations
Probability of Simple Events
The Addition Rule
The Multiplication Rule
Conditional Probability
Counting Techniques
Probability Distributions
The Binomial Probability Distribution
The Poisson Probability Distribution
The Standard Normal Distribution
Applications of the Normal Distribution
Assessing Normality
Sampling Distributions
The Central Limit Theorem
Confidence Intervals about $\mu$, $\sigma$ known and unknown
Confidence Intervals about the Population Proportion
The Language of Hypothesis Testing
Testing a Hypothesis about $\mu$, $\sigma$ known and unknown
Testing a Hypothesis about the Population Proportion
Confidence Intervals about $\sigma$
Testing a Hypothesis about $\sigma$
Chi-Square Goodness of Fit Test
Contingency Tables; Association
Chi-Square Test for Independence
Appendix B – Sample Study Survey

Statistics Student Survey

The following items are purposely broad, to allow you the most freedom in responding to them. Feel free to respond openly and as completely as possible – use the reverse side if more space is required.

Please describe what you see as the ‘purpose’ of statistics.

Please explain the concept of ‘mean’ as you understand it.
### Appendix C – Quantitative Results from Student Survey Evaluation

#### Item 1

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#### Item 2

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![Chart for Item 1](chart_item1.png)

![Chart for Item 2](chart_item2.png)
List of Works Cited


