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Drawing Normal Curves: A Visual Analysis of Feedback in Writing-To-Learn Assignments in an Introductory Statistics Course for Community College Students

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Writing-to-learn benefits students in polishing their communication skills and understanding of statistical concepts cultivating a deeper understanding of statistics. A series of writing-to-learn activities were given to introductory statistics students at a community college in the Rocky Mountain region of the United States. Historically, research on the teaching and learning of statistics has been performed on undergraduates while overlooking the experiences of community college students in learning statistics. A total of 79 students completed the feedback instrument over the course of three semesters (Summer 2017, Fall 2017, and Spring 2018). The feedback instrument included three Likert scale questions, two open-ended questions and a prompt to draw their feelings about the writing assignments and statistics course. Research suggests that drawings are a creative and novel form of collecting student feedback. Data were analyzed using descriptive statistics where appropriate, thematic analysis was used to evaluate written responses, and visual thematic analysis was performed on the drawings. Findings are useful to introductory statistics instructors and statistics education researchers in understanding the students' experience with writing-to-learn assignments as the responses provide insight, feedback, and drawbacks on the assignment. Keywords: Community College, Statistics, Writing-To-Learn, Visual Thematic Analysis, Drawings, Thematic Analysis

Introduction

In order to improve writing and critical thinking among students in the 1970s, the Writing Across the Curriculum movement was implemented by colleges and universities (Bazerman et al., 2005). By the 1980s, the movement had reached disciplines such as mathematics and statistics (Woodward et al., 2019). Hayden (1989) wrote about the usefulness of utilizing writing to teach statistics. The author had concluded that the students in the statistics course were simply "tossing a coin" when responding to statistical problems, thus teaching them computational skills was not a good use of instructional time. Instead, Hayden focused on evaluation and interpretation as part of this new teaching approach which included the introduction of writing assignments to assess the comprehension of statistical concepts. Nowadays, focusing on evaluation and interpretation of statistics is common practice in statistical courses particularly those taught within disciplines outside of mathematics such as sociology, psychology, and nursing among other fields. Statistical literacy is an important component of statistics education as a basic understanding of data and figures is necessary to make sense of everyday life in the form of public health figures, educational statistics, and budget predictions. A number of papers exist focused on developing statistical literacy through writing (Delcham & Sezer, 2010; Goenner & Snaith, 2003; Johnson, 2016; Parke, 2008, Smith et al., 1992; Woodward et al., 2019). Yet, few of them have assessed the students' perspective

of completing these activities (Smith et al., 1992). In this study, I implemented a writing-to-learn assignment among community college students in an introductory statistics course focusing specifically on students' feedback of the activity through student generated drawings along with open-ended responses to gain the students' perspective on writing-to-learn activities.

Literature Review

Statistical Literacy

As the interpretation of data and statistics continues to shape the world, cultivating statistical literacy remains an important goal in quantitative courses. For example, the most recent Guidelines for Assessment and Instruction in Statistics Education (Guidelines for Assessment and Instruction in Statistics Education, 2016) report details "interpretation of results should be emphasized in statistics education for statistical literacy" (p. 9). Gal (2002) defined statistical literacy broadly as a two-fold concept: (a) the ability to interpret and evaluate statistical concepts and (b) learning to communicate the results of a statistical process. Likewise, Ziegler and Garfield (2018) define statistical literacy as "the ability to read, understand, and communicate statistical information" (p. 162). Ziegler and Garfield's definition of statistical literacy does apply only to students, but such reasoning and understanding can be used by anyone. Engel (2017) stated that any individual "empowered to study evidence-based facts and that has the capacity to manage, analyze and think critically about data is the best remedy for a world that is guided by fake news or oblivious towards facts" (p. 45). For example, the comprehension and interpretation of unemployment records, public health figures, and education statistics all rest on the assumption that good statistical literacy has been instilled during high school and college. The "enlightenment" of individuals begins with statistical reason and quantitative reasoning (Engel, 2017, p. 45).

Benefits and Guidelines for Writing in Statistics

In fact, a number of organizations support the instruction method and scholars have focused on creating multiple activities to implement writing in mathematics and statistics (Johnson, 2016, Woodward et al. 2019). The use of written assignments in an introductory course in statistics targets many of the goals set by GAISE (2016) including statistical literacy. Briefly, the goals of GAISE (2016) are (a) students should become critical consumers of statistical information in the media, (b) students should recognize the appropriate statistical procedure for a particular question, (c) students should be able to produce graphical descriptive information, (d) students should be able to understand and explain variability, (e) students should understand the use of statistical models, (f) students should understand the concept of statistical inference, (g) students should gain experience with technology used in statistics, and (h) students should be aware of ethical issues in statistics.

Likewise, the Association for Psychological Science (APS) published guidelines on how to incorporate writing into the teaching of statistics in its Teaching Tips feature encouraging faculty to integrate the technique in their teaching highlighting three major aspects: (a) writing to minimize anxiety, (b) to deepen conceptual understanding, and (c) develop statistical thinking and reasoning skills (Holmes, 2012). Similarly, the Principles and Standards for School Mathematics recommended the use of written assignments to assess students (National Council of Teachers of Mathematics, 2000). The interest of these organizations in incorporating writing into statistics shows that it is an important interdisciplinary goal in order to instill statistical literacy.

Within the statistics education literature, multiple researchers have shared the numerous benefits to incorporating writing in statistics to both student and instructors. Researchers and educators have studied the writing-to-learn method in the past which consists of assigning either a prompt related to statistical (or mathematical) concepts to which students can explain the significance of a concept, the reasoning on how to solve a problem, or the use of a certain technique (Johnson, 2016; Radke-Sharpe, 1991; Smith et al., 1992). Supporting Hayden's (1989) argument, Shibli (1992) stated that the use of writing prevents students from falling into the trap of memorizing the formulas and forces students to articulate their thought process which results in "better internalization" (p. 126). The benefits of the writing-to-learn method are numerous and include (a) improving writing skills, (b) internalization and conceptualization of the statistics material, (c) encouraging creativity, and (d) improving communication skills regarding methodology and drawing conclusions (Johnson, 2016; Radke-Sharpe, 1991). Furthermore, the writing-to-learn assignments are also useful to instructors allowing them to glimpse the thought process of students. For example, instructors were able to follow the decision-making process of students when checking for statistical assumptions of a test (Woodward et al., 2019). While the writing-to-learn process encourages creativity, it may also cause difficulties for the instructor when it comes to creating a rubric and grading. However, the existing literature of writing-to-learn assignments primarily focuses on applications of writing-to-learn with little emphasis on students' perspectives, in addition to the sharing of activities for other instructors to implement. Next, I will review the available writing-to-learn focusing specifically on the field of statistics.

Research on Writing-to-Learn in Statistics

Researchers and educators have executed a variety of action plans to implement the writing-to-learn method in statistics courses as a low-stakes assignment in a variety of populations (i.e., undergraduate, graduate) as well as content areas (i.e., mathematics, psychology statistics, business statistics). For example, Smith et al. (1992) conducted a survey research study in undergraduate business statistics courses to examine if the writing exercises improved students' understanding of the content and their attitudes toward the writing-to-learn activities. The authors assigned prompts to the students throughout the course of the semester which were graded for completion. The author examined the descriptives (i.e., means and standard deviation) of a feedback survey, along with open-ended responses from the students regarding their attitudes toward the writing-to-learn exercises. The authors found no correlation between GPA and the students' perception of the value of the assignments. In a different observational study Stromberg and Ramanathan (1996) studied the use of peer evaluation. Students were responsible for reviewing the statistical content of an article from a newspaper or magazine and then engaged in peer evaluation of their written work during class. The authors concluded that the activity addressed one of the key points of why students did not perform well in written assignments such as failing to read the assignments' instructions correctly. Additionally, the authors empirically compared the grade of the students with and without the peer evaluation activity finding that the students who engaged in the peer evaluation activity had higher grades on the written assignments. Next, Parke (2008) incorporated a similar activity, but focused on graduate students in which they engaged in student-guided discussion of the statistical content and reporting of journal articles. The students' own reports were compared to those of students who did not engage in such activities. Parke developed a list of elements that the students should be able to describe in their own writings. This list included items such as "mentioned the independent variable" and "included the t-value and the associated degrees of freedom." As anticipated, when comparing the groups, students who did

engage in the instructional approach had higher percentages of correctly including the elements in the list.

A common approach to writing-to-learn assignments is to create multiple small-scale assignments throughout the semester. Goenner and Snaith (2003) applied small scale writing-to-learn activities with a business statistics course focusing on the data analysis and developing business memos. Goenner and Snaith's paper primarily focuses on sharing the activity so that other instructors can utilize it in their own courses; additionally, the authors stress how it can help incorporating writing in statistics though it can cause the instructor to become overburdened by the amount of grading. Lastly, Delcham and Sezer (2010) utilized staged writing assignments throughout the course leading to a final paper in an introductory course. The writing assignments implemented focused on a variety of topics such as critical thinking and comparing and contrasting. Anecdotally, the authors concluded that the staged written assignments gave the instructor a "critical insight into student learning and allow[ed] them to make a timely instructional additions and adjustments" before students completed the final paper (p. 512). Most recently, Woodward et al. (2019) reviewed a four-step process of implementing writing in statistics. The idea was to have students answer a prompt in the context of the statistics course, state the relevant facts and implications, and finally explain how these lead to the statistical conclusion. The authors believe that the four-step process allowed the instructor to assess all the processes that lead to statistical literacy. Like previous authors, Woodward et al. shared the activities used in the course so that instructors can make use of them. Though not tested empirically, the authors believe the assignments were useful tools for the instructor to gain insight on the students' thought processes.

The majority of the available literature focused on a variety of populations in a university setting (i.e., undergraduate, graduate) in addition to different fields (i.e., business, psychology, mathematics). Researchers focused on having the students examine their own writing of statistical content or having the students criticize or review the statistical content of available articles or news pieces or giving the students a writing prompt (Smith et al., 1992; Woodward et al., 2019). In many instances, the researchers made the writing-to-learn activities a low-stakes activity in which students received credit for participating in the activity (Smith et al., 1992; Stromberg & Ramanathan, 1996). Finally, it is important to note that there is a wide range of approaches within the available literature. In general, the available literature focuses on the sharing of the activity, comparing the student's improvement in writing to a control, identifying a pre-post writing improvement, and the writing-to-learn success is viewed through the lens of the instructor (Hayden, 1989; Woodward et al., 2019).

While participants in these studies showed improvement in their understanding and learning of statistics, few of these studies focused on the participant's perspective of the activity. Thus, I emphasized this in the present research by utilizing a qualitative approach which is the best method to give voice to the participants. Similar to research by Pitt (2017), who successfully assessed students' perspectives on class assignments utilizing a visual method such as drawing, I set to collect student feedback of the writing-to-learn activities through a combination of drawings, open-ended questions, and three Likert items.

Visual Research

Visual research in the social sciences has become a popular research tool within the last decade (Emmison et al., 2012; Forrester & Sullivan, 2018). Emmison et al. proposed a participant-centered approach which focused on actively involving research subjects when conducting visual research (2012). Further, Pitt (2017) suggested that drawing as a method can be used for qualitative research as well as a teaching tool, advocating for drawing as a data collection technique within teaching. Pitt states that drawing gives understanding to "lived

experience and opportunity to articulate the minutiae and nuances of everyday life in a mutually supportive and constructive environment" (p. 42). One benefit of visual methods is that they are not restrained by language (Literat, 2013). Pitt (2017) adds that the method can be fun for the participant. Another advantage is how this method requires very little in terms of equipment: paper and pencil. Pitt (2017) states:

> Participants can utilize a method such as drawing to represent concepts, emotions and information, which is not always possible through writing or oral diction, which by definition are bound by temporal logic. The participant-generated images act as a graphical metaphor, which represents the often-unseen experience of the individual. (p. 87)

Participants' drawings allow the researchers a glimpse of the participants' thoughts in a manner in which oral or writing communication cannot.

Researcher Stance

I started teaching introduction to statistics for a mathematics department as a graduate student. As is very common for graduate students, I soon found myself teaching part-time at the local community college to support myself through my graduate degree. In a community college setting, it is common to have returning students experiencing mathematical anxiety; more than once, I was told at the beginning of the semester "I have not been in school in 34 years" or "I haven't done math in 10 years." After a couple of semesters, I understood this was how students let me know about their anxiety toward the class. However, student anxiety definitely made me rethink my teaching strategies. Many times, students are able to solve statistical problems "mechanically" (e.g., hypothesis testing) when guided by a sequence of steps, to solve a hypothesis testing problem to a degree of correctness, able to write a hypothesis, find a critical value, and calculate a test statistic, but less often can they write a conclusion for the test. Certainly, it is more difficult to communicate the results of their test than it is to calculate; however, it is also true that communicating results will be the most useful skill students gain from the course (assuming students can always be aided by technology when in need of a statistical calculation). Having attended multiple professional development workshops, I became certain that having a variety of assignments helped students understand the content material better. In other words, I was encouraged to have a class that was not always focused on exams and homework. I was advised on many different techniques, many of them quite unorthodox, for example, have students bring a song to class and analyze it (I was never able to figure how to do this in the context of statistics); have them use software (unfortunately not all students have the resources or computer literacy and as an adjunct instructor one is rarely paid office hours needed to support students with their technology issues); or incorporating writing (bingo!).

Incorporating writing into my statistics course was the most cost-effective solution for me as an adjunct instructor, as well, I believed it perfectly matched my social efficiency ideology as an instructor. Social efficiency focuses on the instructor developing essential societal skills in their students (Alanazi, 2016). I believe that developing students' writing aided them in both interpretation of statistical content in addition to giving them the experience of writing about statistical content which can be asked of them in the workplace or in everyday life. Recall that statistical literacy shapes students' critical skills so they can objectively interpret everyday data (Engel, 2017). Thus, I wanted to focus on developing my students' statistical literacy through the writing-to-learn assignments so that they could apply concepts to the real world rather than focusing on problem-solving and receiving a passing grade. As an

additional benefit, I hoped the writing-to-learn assignment would work to the advantage of those students who had difficulty with the mathematical side of statistics but considered writing their better skill.

Purpose and Rationale

The following gaps emerged in the statistics education literature. First, while there is plenty of literature in teaching introductory statistics courses, none have focused on community college students' experiences in learning statistics. Second, the use of drawings in social research is commonly utilized, particularly in arts-based research (Theron et al., 2011), research with children (Literat, 2013), and with patients' perceptions of illness and treatment (Cheung et al., 2016); few instances have used the method within teaching or assignment feedback from students (Pitt, 2017). Third, though research has been performed on the writing-to-learn method, these studies have mainly focused on transferring knowledge from instructor to instructor. In other words, these publications focused on why the method is beneficial and how to do it within one's own class. Few studies have focused on the students' experiences with the writing-to-learn assignment (Smith et al., 1992).

Thus, the purpose of this study was to implement the use of writing assignments in an introductory statistics course and gather feedback and understanding from the students' perspective on the writing-to-learn activity. The research questions of this study are the following:

> RQ1. What were the experiences of introductory statistics community college students when completing writing-to-learn assignments?
>
> RQ2. How does a group of introductory statistics community college students depict their experience with writing-to-learn assignments?

Methodology

I obtained Institutional Review Board (IRB) approval for this study before data collection began. For the present study, I chose a qualitative methodological framework based on thematic analysis of participant-generated drawings and written responses. Additionally, I examined three survey items through descriptive statistics. To keep responses confidential, I did not ask for demographic information from the participants. I focused the questions of my survey on the writing-to-learn assignments. Thus, the setting and participants are described in aggregate form within the context of the institution.

During the summer of 2017, and the academic year of 2017-2018, as an adjunct faculty in a community college in the Rocky Mountain region of the United States, I implemented writing-to-learn assignments in an introductory statistics course. The most recent demographic information available on the community college's website from Fall 2015 is the headcount of students: N = 5,298. The distribution of ethnicities is as follows: 32.69% identified as Hispanic or Latino, 0.42% identified as Native American, 1.25% as Asian, 1.85% as African American, 0.21% as Native Hawaiian or Pacific Islander, 59.53% as White, 2.10% identified themselves with two or more races, 1.66% did not disclose their ethnicity and finally, 0.30% instead of selecting an ethnicity identified as Non-Resident Alien. Additionally, gender was distributed as 58.51% females and 41.49% male. The type of credits taken at the institution is 53.07% as transfer credits, 33.91% vocational credits, 13.02% developmental credits.

Setting

The course of Business Statistics was cross listed with Introduction to Statistics course thus students from both courses completed the assignments and feedback of the writing-to-learn assignment. Students self-selected themselves into the course once they had completed the prerequisites (a score of 21 in the Math ACT or a grade of C or better in Intermediate Algebra). Due to the course being part of the common core classes there was a variety of majors in the class: pre-nursing, human services, psychology, and criminal justice among others. A number of them were enrolled at the local university and were planning on transferring the course. A total of three writing assignments were assigned throughout the semester. The first one provided a "news" piece to students to examine the research design. The news articles chosen were Musulin's (2014) article on textbook prices, and *Science Daily*'s article on a live theater experiment (2014). Students also had the option to find their own news article. The second writing assignment was based on Smith et al. (1992) writing assignments for an introductory statistics course and focused on the standard deviation. Details on this assignment can be found in the Smith et al. (1992) paper. Finally, students were provided an article for the topic of correlation and regression namely Messerli's (2012) article on chocolate, cognitive function, and Nobel laureates. The reason why this article was chosen was because the use of correlation and regression is clear and simple enough for introductory students. These assignments consisted of asking students to write their understanding of statistics rather than providing a computational answer. At the end of the semester, students were asked to provide feedback on the usefulness and perceptions of the assignments. The instructions for the assignments can be found in Appendix A and the instrument can be found in Appendix B.

Participants

Further, participants were 18 and older while enrolled in the statistics sections I taught over the course of three semesters. Verbal consent was obtained as students were asked to complete the feedback of the writing-to-learn assignment; additionally, the students were reminded that they could "opt-out" of providing feedback. The students were told their thoughts on the assignments were needed in order to improve them or eliminate them. Thus, purposeful sampling was used in this study to select participants who could provide the most insight regarding the topic of interest (Merriam & Tisdell, 2016). A total of N=79 participants provided feedback on the writing-to-learn assignments over the course of three semesters.

Data Collection

While I implemented the writing assignments throughout the semester, data collection on the student feedback of the activity was done once per semester usually once the third assignment was completed (2 or 3 weeks before the semester would end). Shortly after the third assignment was completed, I asked the students to complete feedback on the assignments. The idea was to gather feedback on what worked and what did not. For this purpose, I allowed 20 minutes at the end of class to complete the feedback of the writing-to-learn assignments. I distributed the data collection instrument (see Appendix A) and explained to them what the purpose of the feedback was to help me improve the assignments and their understanding of class concepts. I also asked them not to provide any identifiable information in their feedback.

The instrument of data collection I used for this study was a one-page form with three sections: three Likert scale items, open-ended questions, drawings. The purpose of combining the multiple means of collecting data such as Likert scale items, open-ended questions and drawings was to yield more robust and rich findings (Snyder, 2012). Moreover, participants

were reminded that they could choose not to participate and leave the feedback blank, in addition to not disclosing their name on the feedback paper. Additionally, I conveyed to the participants I would not look at the feedback until semester had finished. My reasoning was that I wanted to avoid inadvertently recognizing a student's writing.

The students were asked three Likert-type questions. These questions were based on Smith et al.'s (1992) work, one of the first exploratory studies on using writing in statistics, thus it seemed reasonable to emulate their questions to gain feedback from students. Smith et al.'s (1992) questions focused on the helpfulness of writing assignments and how these helped communicate statistical concepts. My first two questions targeted helpfulness and the ability to communicate statistics concepts as Smith et al.'s had (1992) whereas the third question I created focused on communicating about research. The questions could be answered with a Likert type scale in which the participants could rate the assignments from 1 = "Not helpful" to 5 = "Very helpful":

1. Rate how helpful the writing exercises in learning statistical concepts are.
2. Rate how helpful the writing exercises in developing your ability in writing and talking about statistics are.
3. Rate how helpful the writing exercises in developing your ability in writing and talking about research are.

In addition to these three questions the students were asked to share a brief sentence on the usefulness (or lack of) of the assignments in the following open-ended questions:

1. Please share your overall thoughts on the written assignments (positive, negative, neutral feelings are all welcome). Typical responses to this question were simple phrases of "neutral" or "I think they are ok." However, when students felt the assignments were useful, they would mention how the assignments "ensures class wide understanding" and "helpful in understanding concepts."

2. Please share any suggestions you have on improving the written assignments. Typical answers would range from uncertainty from the student requesting to have writing assignments in class where I could give immediate feedback and examples to students describing the assignment as "too easy." A number of students also suggested loosening up the word limit requirement.

The idea behind the open-ended questions was to triangulate responses later in the analysis. Collecting similar information in different formats in order for one collection form to complement the other; for example, a student may decide not to draw, but may be inclined to answer the survey items, or a student may draw but may not respond to the open-ended questions.

Finally, the students were asked to draw their experience or feelings when completing the writing assignments. In the instructions, students were asked to be creative in the drawing section and read "Draw your experience/feelings completing the written assignments of the written assignments. You can use any color pencils or markers (Hint: be creative)." The participants were responsible for drawing and providing context to their answers thus they retain control in the power relationship with the instructor (Pitt, 2017). In terms of the representativeness of the sample, recalled purposeful sampling was utilized; thus, data collection focused exclusively on students who completed the writing-to-learn assignments while allowing participants to decline participation if they so desired.

Data Analysis

The method I chose to analyze my data was thematic analysis. Thematic analysis is a popular approach for analyzing qualitative data and can be used for a variety of content areas and has been used successfully to analyze student reflections and when researching visual methods for this reason I thought it would appropriate to use for the data I collected (Davies & Bourke, 2017; Freeman, & Sullivan, 2018; Rookwood, 2017). The process of thematic analysis identifies emergent themes and provides a substantial and detailed information of the data (Braun & Clarke, 2006; Taylor et al., 2015). Thematic analysis is useful for summarizing information from large datasets which the student-generated drawings in combination with open-ended responses created (Nowell et al., 2017).

I took an inductive approach, meaning I did not analyze data until I had completed data collection over the course of the three semesters, so that I could code the data as a whole as opposed to an iterative process where I could inadvertently change my process, as a considerable amount of time passed between each data collection period (at least one semester). Thus, the data were coded once it was possible to examine it in context of the complete dataset (Basit, 2003). Part of the organization process included the scanning of the student feedback drawings, data entry for the Likert items, and transcribing of the open-ended questions.

Data Management and Coding

The first step in conducting thematic analysis was to familiarize myself with the data (Freeman, & Sullivan, 2018). I familiarized myself with the data by reading the student feedback multiple times before I entered the data in a spreadsheet. The process of data entry also helped me become familiar with student responses while making notes in color in the spreadsheet of where I would code certain responses. I re-constructed the data in a spreadsheet with the Likert items and open-ended questions. I created a random ID, so it was possible to connect the paper version of the feedback to the data file. Next, I also scanned the paper version of the feedback, then I took screenshots of the student-generated drawings and added the drawing to the corresponding participant in the spreadsheet. This allowed me to easily view the responses as whole as opposed to individual sections thus helping me create initial themes for the analysis. This reconstruction of the data in digital form allowed me to add my own notes to the participant generated responses in addition to color coding the themes.

The second step in conducting thematic analysis was to generate initial coding (Freeman, & Sullivan, 2018). Initial coding was relatively fast, drawing from my teaching experience, I expected students to lean heavily toward "neutral" (Given, 2008). I attached codes to the open-ended questions as well as the drawings by adding a column and within this column a written code and distinct color for the code. For instance, many of the student generated drawings were describing a process going from confused face to understanding or "lightbulb" moment (see Table 5 and Figure 7) next to these drawings I would add a note "student process." When coding, memos can help the researcher move from coding to relating concepts and establishing relationships (Weaver-Hightower, 2018). Thus, I also included memos on how a student's feedback reoccurred in another students' feedback (by making a note of their IDs, for example a note would read "ID 23 similar thoughts to ID 54"). This data management work facilitated the organization, search, and retrieval of codes (Given, 2008).

The third step focused on generating the themes (Freeman, & Sullivan, 2018). I considered the relevance of each code to the research questions I wanted to answer and how each code related to the data as a whole (Given, 2008; Weaver-Hightower, 2018). I wanted to see what the experiences of the students while completing the writing-to-learn assignments were. This process led to a data condensation of simple inductive themes of "Student liked the

assignment" or "Student didn't like it," or "neutral." It was a complex task to code the neutral category as it could range from simple indifference by the student indicated by simply writing "neutral" along with a smiley face or the student could provide more context as to why they felt neutral. In the cases where the student did provide context, I created subthemes within the neutral category, and an additional memo for that piece of data (Weaver-Hightower, 2018). For example, student responses such as "do more examples of them in class" and "maybe extend the writing assignments to in class" would get a memo similar to this: "They want the assignment discussed in class/More context in class/More hand-holding." Another example of a subtheme within the neutral category was when the student seemed focused on completing the assignment but did not feel they gained from it, for example, "I believe they may be helpful to some.' but I personally don't feel I gain much from them. I don't mind the assignments though" and another "I think they are ok, but I don't feel like they help me to learn or understand." In this same category, another participant simply left blank and drew a completed check in the drawing section of the data collection tool (see Table 3). For these types of responses, I would create a note: "No personal gain/Just wants to complete the assignment."

In the fourth step I reviewed the codes and began extracting data. I looked for the extracted data to have a coherent pattern, focusing on reviewing themes and extracting the data of the open-ended responses and drawings aggregating for easy access when I began writing (Freeman, & Sullivan, 2018). Once I was satisfied with the themes, I finally labeled the final three themes as Not Helpful, Neutral, and Very Helpful. As described earlier, within these themes exists subthemes which are discussed further in the findings.

Trustworthiness

I used triangulation to enhance trustworthiness in the form of using multiple sources and to decrease researcher bias (Denzin, 2017). When utilizing drawing as a research method, it is recommended that participants either discuss or write about the content of their drawings. This is an important part of the research due to the fact that a drawing by itself can be neutral, so it was important to give context to the drawing by asking students open-ended questions (Mitchell et al., 2011). Next, I focused on methodological triangulation, that is corroborating findings through the different data collection methods: open-ended questions, drawings, and Likert items (Weaver-Hightower, 2018). For the methodological triangulation the survey items, along with written responses and drawings, were used to explore the students' feedback of the writing-to-learn activity. Initially, I focused on the open-ended questions since students were more likely to offer a written response than a drawing then I would add a memo to the spreadsheet describing the relationship. Next, I would examine the relationship between the open-ended response and survey responses; for example, survey items aligned with the comments. For example, the following open-ended response "I don't care to do them, it's well meaning [*sic*], but needs development" was corroborated by low ratings in the survey.

Next, I proceeded to analyze the responses to the short survey items.

Findings

The findings will be presented in the following order: descriptive information from the Likert items will be presented followed by a qualitative thematic analysis of both open-ended questions and participant generated drawings. The data collection instrument can be found in Appendix A.

Survey Items

Descriptive statistics were calculated utilizing the R statistical package while graphics were obtained through the cowplot package (R Core Team, 2013; Wilke, 2019). Table 1 shows the descriptive information for the three Likert items. Note that there were no missing data for the Likert items and the sample size was N=79. The distribution of item responses was as follows: "Rate how helpful are the writing exercises in learning statistical concepts?" 2.5% of the students found it "Not helpful", 48.10% of the students found it "Somewhat helpful" and 11.39% found it "Very helpful." Next, participants were asked "How helpful are the writing exercises in developing your ability in writing and talking about statistics?" the distribution of responses was as follows: 2.53% as "Not helpful" and 36.70% as "Somewhat helpful" while 15.18% found it "Very helpful." Finally, in response to "How helpful are the writing exercises in developing your ability in writing and talking about research?" the majority of the students found it "Somewhat helpful" 35.44%, and 13.92% of students found it "Very helpful," while only a minority of students found it "Not helpful" at 3.79%. Figure 1 shows the distribution of responses for the Likert items. Examining the three charts it is clear that few students selected the "Not helpful" option.

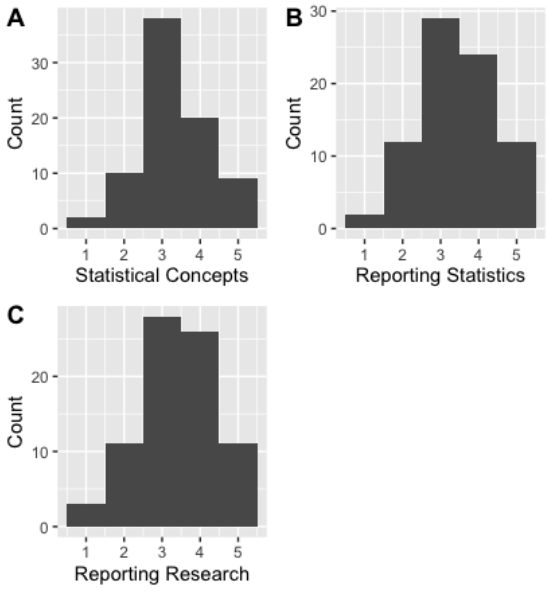
Table 1

Descriptive statistics for Likert items

	Items	M(SD)
1.	How helpful are the writing exercises in learning statistical concepts?	3.304(0.924)
2.	How helpful are the writing exercises in developing your ability in writing and talking about statistics?	3.405(1.000)
3.	How helpful are the writing exercises in developing your ability in writing and talking about research?	3.392(1.001)

Figure 1

Frequencies for Likert items: A) How helpful are the writing exercises in learning statistical concepts? B) How helpful are the writing exercises in developing your ability in writing and talking about statistics? C) How helpful are the writing exercises in developing your ability in writing and talking about research?



Visual Thematic Analysis

Examining the drawings simultaneously with the written responses, the following themes emerged: the students felt they either disliked or liked the assignments with the only other category being neutral toward the assignments. However, to be consistent with the survey responses, the major themes were classified as not helpful, neutral or very helpful.

Theme #1: Not Helpful

Students who disliked the assignment had a theme in common: They believe the assignments needed more development or they were not challenging enough. When examining the student generated drawings, it is clear they expressed these thoughts through the use of question marks (see Figures 2 and 3).

"They're too easy and require too little thought."

"I think the writing assignment would be more helpful if they were more challenging and if they were more focused on the stats part rather than the writing part."

"I don't care to do them, its well-meaning but need development."

"The assignment seems like it's more about filling a standardized expectation that about getting the concepts."

"I didn't like them but I'm lazy. If you want to practice the skills with this kind of exercise, then make more written assignments."

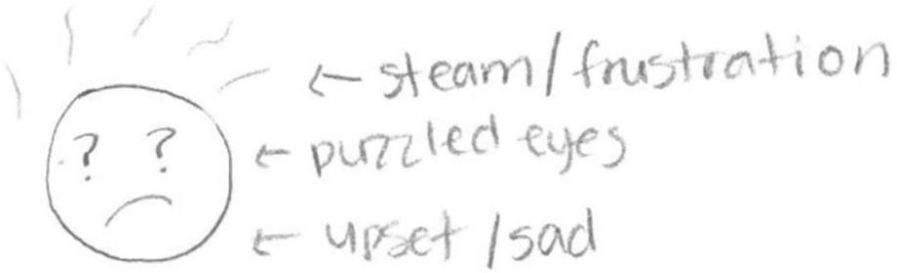
"Maybe have a few more?"

Figure 2
"I didn't like them but I'm lazy. If you want to practice the skills with this kind of exercise, then make more written assignments."

While students rated the assignment low, few declared they disliked the assignment because it was difficult. Most of them found the writing-to-learn assignments not challenging as the earlier quotes show. One student simply wrote "Not useful." Finally, only one student declared his/her dislike based on struggling with the material this theme was more common among students that rated the assignments as "neutral." Shown in Figure 3, the student drew out his or her frustration with the content of the writing-to-learn assignments:

"I personally don't like them because I don't understand most of the material on them. I can barely keep up in class + the written assignment confuse me."

Figure 3
Dislike for the writing-to-learn assignment based on difficulty with the material



Theme #2: Neutral

Students who rated the writing-to-learn assignments as neutral can be divided into two categories: focusing on completing the assignment (most likely so that their overall grade in the class would not be affected) and struggling to make connections between the assignment and class material. The participants in Table 2 rated the assignment neutral though they struggled to find the connection between class material and the writing-to-learn assignment as the following participant states:

"I'm not a huge fan of the writing assignments because I get confused . . . or coming up with."

Note that "emoticons" are often used by students in their drawings. In this theme, many of the faces have a neutral, almost emotionless face (see Table 2). More importantly, the struggle of these students to connect the writing-to-learn assignments and statistical concepts covered in the course supports Shibli's (1992) argument that writing requires more insight into the statistical concept compared to mechanical calculations.

Table 2
Summary of participant quotes and drawing for those participants that rated the writing-to-learn assignment as neutral.

Participant's quote	Participant's drawing
"If they weren't so "wordy" they would be more manageable to read and respond about."	

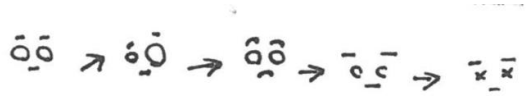
"I think written assignment #3 has been the most helpful in understanding concepts like standard deviation."

"More structure, I'm a very needy person when it comes to what I need . . . to write about or I go off and [do] a different thing."

"They don't really help me make a straight correlation of whats [*sic*] going on in the class w/ the written assignment."

"I think they are ok, but I don't feel like they help me to learn or to understand."

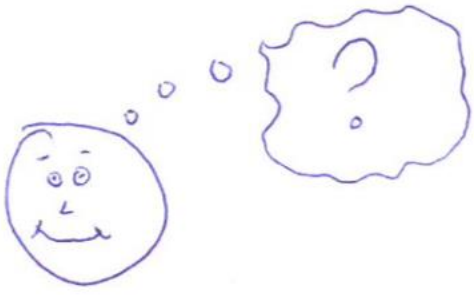
"At this point if [*sic*] neutral, I personally didn't grasp WA#1."



Neutral

"They are good up to a point which they help you with your writing and being able to understand how to solve problems, but sometime[s] they can become hard to understand."

"I am a visual learner, therefore trying to visualize something in writing is difficult for me."



There were also students who simply completed the assignment and the feedback instrument for the sake of completion. In Table 3 there are examples of how students thought of the assignments as simply something that must be completed in order to advance in the course. See Table 3.

Table 3
Participants focused on completion.

Participant's quote	Participant's drawing
Blank	
"I don't like writing"	

Similarly, a number of students had positive reflections on the assignments though they did not feel the assignments helped them personally to develop their statistical knowledge. Table 4 displays the participants' quotes alongside their respective drawings for the students with these opinions.

Table 4
Quotes and drawings on the writing-to-learn assignments not being personally helpful

Participant quote	Participant drawing
"I believe they may be helpful to some but I personally don't feel I gain much from them. I don't mind the assignments though."	
"Neutral, they are helpful but can be time consuming"	

The participants also discussed how to make the assignments better. One of the suggestions was to include the writing-to-learn assignments in class rather than assign them as homework. This could indicate the students do not actually feel comfortable with the writing-to-learn assignments and would like to have the instructor present to have more guidance though the participants do not explicitly say so. Among the suggestions was to add the writing-to-learn assignments to the class session:

"Do more examples of them in class."

"Maybe extend the writing assignments to in class."

"Basically, add the assignments in class."

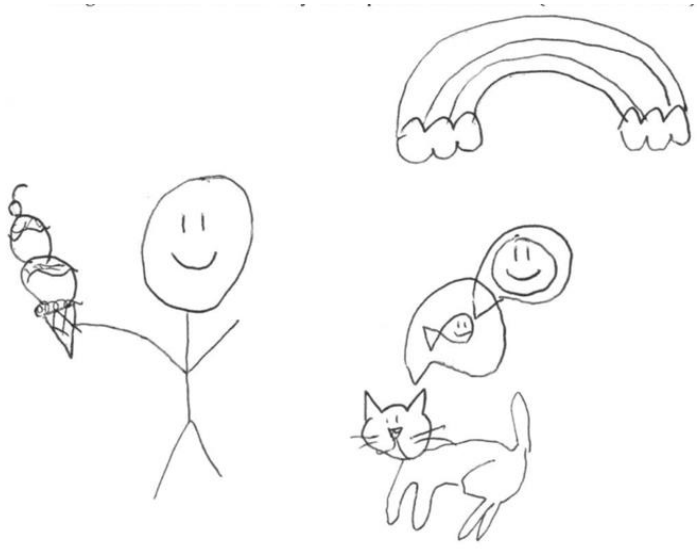
Figure 4

Note how this drawing utilizes the Greek letter □ (upper case M) which symbolized the population mean for this statistics course

Several students mentioned forgetting to complete the written assignments or having completed only one or two out of the three assignments. Finally, a student suggested to increase the word limit he or she found it difficult to keep it under 500 words. A student declared, "I kind of like the writing assignments because it is not opinion-based writing, you just explain something that is already there" (see Figure 5). However, another student agreed that the use of the writing-to-learn method was a "creative method of applied learning."

Figure 5

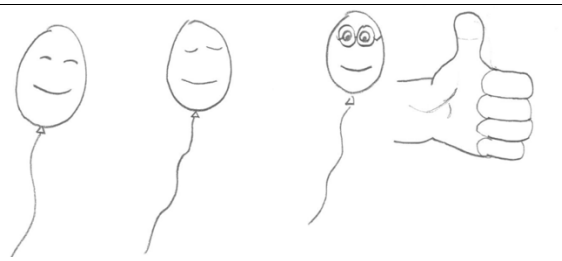
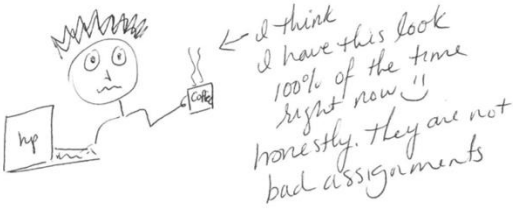
"I kind of like the writing assignments because it is not opinion-based writing, you just explain something that is already there."



Theme #3: Very Helpful

Finally, a number of students stated they found the writing-to-learn assignments useful and had positive comments regarding the assignment. Table 5 has a compilation of these responses alongside their respective drawing. There were positive reactions with short and simple statements as "I think the written assignments are great!" Among the drawings notice the increased use of smiling faces.

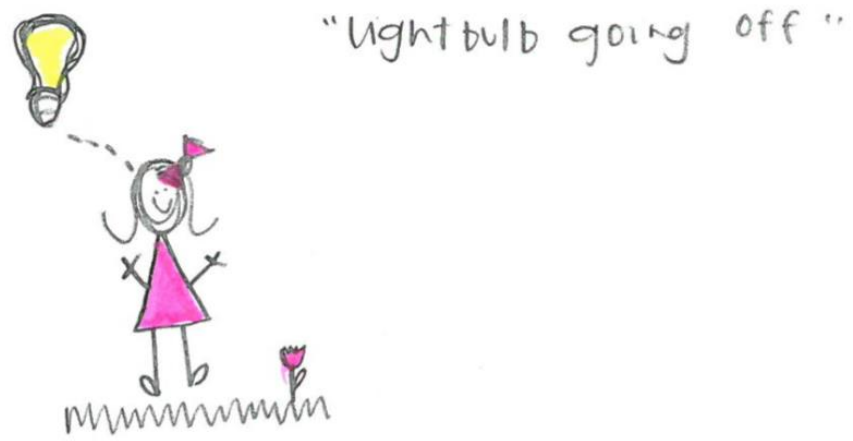
Table 5
Positive and useful

Participant's quote	Participant's drawing
"I don't totally dread the writing assignments so long as they are pertinent to what we are discussing in class and fairly short (so far they have been) 😊."	
"Positive I really enjoy putting what I learn into words. It gives me confidence 😊."	
"I like them [the writing assignments] they're something I wasn't expecting from a math class + make learning the material more interesting."	
"The WA [writing assignments] are very helpful because you practice explaining the problem."	
"Assignments are helpful to talk about statistical information – broadens the knowledge gained from just equations and numbers to analytical exercise."	

More importantly, there was a clear pattern of drawing a lightbulb going off, in fact, a participant actually wrote the words in one of the drawings (see Figures 6 to 8). This indicates how the use of the writing assignments helped students think through the class content until finally the "lightbulb went off." This is supported by the following participant quotes and drawings:

"The writing assignments helped me interpret what I was thinking, it was a good way for me to put my work into words and talk myself through problem(s)."

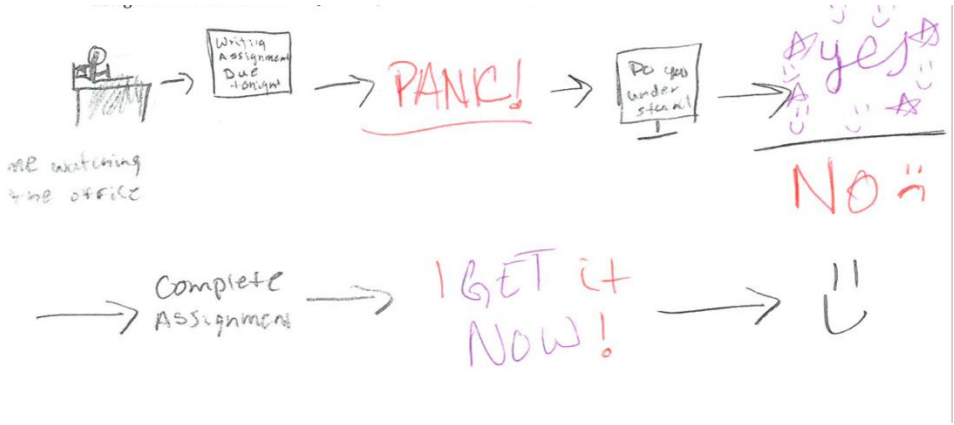
Figure 6
"Lightbulb going off"



"I think the writing assignments help me know weather[*sic*] I understand a consept[*sic*] or not."

"In my opinion, writing assignments show me to describe [the] "big picture" of the provided content."

Figure 7
Student's thought process



"I enjoy the writing assignments. It applies statistics to a real world concept that helps understanding the applications of stats and makes it easier to learn"

Figure 8
Student mood process.

Discussion

Drawing as method of data collection is certainly not without detractors, yet in combination with other data collection elements it was a useful form of collecting student feedback on assignments. Gauntlett (2005) discussed limitations such as drawings by themselves could be too ambiguous, and thus recommends to supplement them with participant interviews. However, to preserve anonymity and due to the number of participants, individual interviews were not possible. Instead, written responses were used. While the majority of the students completed all portions of the data collection instrument (Likert items, open-ended questions, and drawing), missing data occurred only for the open-ended questions and/or drawings. With drawings, resistance can be met by the participants themselves, for example, Table 3 shows a student who left blank the written responses but actually provided a pictorial response. It is important to note that a number of students decided not draw something and submit their feedback and thus were not included in the qualitative analysis. On a positive note, this indicates a level of trust with the researcher and instructor; in other words, participants felt comfortable not participating. The three elements of the data collection instrument not only served for triangulation purposes but to avoid missing data which is a common issue for student feedback.

The use of drawings helped further my understanding of the students' perspectives. If I had simply used Likert items to explore student perceptions of the writing-to-learn assignments, I could have concluded that many students had liked them given the high ratings and skewness of the data. In Figure 1, it is easy to see that the three distributions are left skewed, indicated most students leaned toward the assignments as "Helpful." However, with a more careful look at the written responses, alongside the student generated drawings, I gained more insight into the students' perceptions. Indicating that participant drawings can allow the researchers a glimpse of the participants' thoughts in a manner in which oral or writing cannot. I learned about the students' desire to facilitate the assignment during class, as well as their need for more guidance, and the need of a subset of students for more challenging assignments thus aligning my findings with the ideas postulated by Hayden's (1989) and Shibli (1992). Also, I would like to draw attention to this student quote, "Creative method of applied learning," which resonated with Radke-Sharpe (1991) that writing in statistics encourages creativity.

Finally, the majority of the studies published on the writing-to-learn method in statistics did not represent the students' direct perspective on the assignments. Many studies focused on the development of the activity (Johnson, 2016; Radke-Sharpe, 1991; Woodward et al., 2019), and few of them actually incorporated student ratings via a survey (Smith et al., 1992) and a handful focused on the instructor's perspective of the assignment (Goenner & Snaith, 2003; Woodward et al., 2019). Thus, this study is unique in the aspect of incorporating the students' perspective and feedback of the writing-to-learn method. For this reason, I believe that the findings in this study may be specific to the samples available to me and not generalizable. Though, the teaching tools and feedback process can definitely be replicated by educations and statistics education researchers by examining the appendices of this paper. More importantly, the majority of research regarding teaching of introductory statistics is often performed utilizing samples of university undergraduates. In this sense, this article makes an important contribution to the literature as our distinct sample of community college students is rarely researched. Further, Pitt (2017) suggested that drawing as a method can be used for qualitative research as well as for teaching framework advocating for drawing as a data collection technique within teaching. Drawing as method of data collection offered insight into the assignment that was not always reflected through the quantitative responses; however, many responses relied on written sentences to communicate their responses. In conclusion, the use

of drawing as a method served as a novel approach to receive feedback from students in an introductory statistics course.

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Appendix A

Evaluating a Statistical Study

Choose one of the articles posted in *Online Management System* or you may choose your own article. Summarize the methodological and statistical content from the study. Answer the following questions as best you can from the article. Depending on the article, not all items will be clearly mentioned.

Write no more than 500 words. Submit via *Online Management System*. If you decide to use your own article, make sure you provide enough references (and a link) to find the article.

- Identify the goal or purpose of the study. Include any research questions.
- What type of study did they conduct (qualitative, quantitative, mixed methods, ethnographic, other)?
- Was the study experimental or observational? Why was this appropriate?
- What type of data did they collect? Were the data quantitative or qualitative?
- What population was considered? How large was the sample?
- How was the sample data collected? (Such as surveys, interviews, test scores, and by what technique such as random samples, stratified samples, etc.)
- Were there any confounding variables that can invalidate the study?
- What type of statistical summaries did they discuss?
- How were the data analyzed? (List a few that are mentioned; you do not need to know what they all are unless we discussed them in class.)
- Check the results for misleading graphs or statements.
- Consider the source of the study. Is it reliable?
- What was the conclusion of the study? Does this seem reasonable based on what we have learned so far?
- Anything else you learned from reading the article?

Appendix B

Rate the following:

1. How helpful are the writing exercises in learning statistical concepts? Circle one answer.

Not Helpful		Somewhat Helpful		Very Helpful
1	2	3	4	5

2. How helpful are the writing exercises in developing your ability in writing and talking about statistics? Circle one answer.

Not Helpful		Somewhat Helpful		Very Helpful
1	2	3	4	5

3. How helpful are the writing exercises in developing your ability in writing and talking about research? Circle one answer.

Not Helpful		Somewhat Helpful		Very Helpful
1	2	3	4	5

4. Please share any suggestions you have on improving the written assignments
5. Please share your overall thoughts on the written assignments (positive, negative, neutral feelings are all welcome).
6. Draw your experience/feelings completing the written assignments of the written assignments. You can use any color pencils or markers (*Hint: be creative*)

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