# Developing Critical Thinking in a High School Statistics Class 

Alicia Sussman, M. Ed.<br>Math Department Chair<br>Lea Keil Garson, Ph.D.<br>Math Learning Specialist<br>Director of the Learning Center<br>Reading and Learning Specialist<br>Kohelet Yeshiva High School<br>Merion Station, PA

Submission for The Kohelet Prize
Category: Development of Critical and/or Creative Thinking
November 2016

## Table of Contents

Section Page

1. Developing Critical Thinking in a High School Statistics Class ..... 3
Structure of the unit ..... 3
Teacher reflection ..... 4
Impact on students ..... 5
Adapting the unit across disciplines ..... 5
Adapting the unit for elementary and middle school students ..... 6
2. Opening activity for the unit ..... 7
3. Sample lesson plan ..... 8
4. Directions for culminating project ..... 10
5. Grading rubric ..... 12
6. Samples of student work ..... 13

## Developing Critical Thinking in a High School Statistics Class

"Leading Scientist Shows Bible Proves Adam \& Eve were Astronauts!" This headline from the tabloid National Enquirer would likely engender laughter and disbelief among Kohelet Yeshiva High School students, as well it should. Teenagers are expected to view such a statement from a critical stance and not simply believe it because it's in print. Yet when faced with a similarly outlandish claim involving statistics, most high school students are not as well equipped to evaluate its validity. This disparity may be attributed to several factors, including underdeveloped "number sense," math anxiety, and limited experience in identifying reliable, unbiased data sources.

Alicia's Statistics class for seniors at Kohelet aims to teach students the necessary tools and help them develop the perspective to critically analyze and evaluate numerical and statistical information. Lea's experience as a reading specialist, and both Alicia's and Lea's experience in teaching students with learning differences, makes both of us keenly aware of the importance of teaching critical reading and critical thinking and of creating opportunities for students to practice and develop these skills.

## Structure of the Unit:

The unit that forms the basis of our submission focuses on survey research, a topic that provides a robust and engaging structure for teaching key statistical concepts such as reliability, validity and bias. In addition, a variety of subject matter can be easily incorporated to respond to students' interests and inquiry. As anyone who picks up a newspaper or scans headlines on the Internet knows, the American population is polled continuously on a wide variety of topics, from political preferences and policy positions to spending priorities and leisure activities. Thus, there is a suitable entry point for each student.

Early lessons in the four-week unit introduced students to fundamental statistical concepts through direct instruction as well as analysis of articles that either report statistics or rely on statistics to make a point. Students learned introductory statistical terms and the difference between descriptive and inferential statistics. Each week students had the assignment of bringing in an article (print or online) that involves statistics and answering the following questions about their articles:

1. What is the topic being tested or researched?
2. What is the population?
3. What is the sample?
4. Do you think the research is valid? Why or why not?
5. Do you think the source is biased? Why or why not?

These articles, having the virtue of being selected by the students themselves and therefore of inherent interest to them, generated rich and lively class discussions. They were a fine medium for instruction on critical reading, both on taking a critical stance and recognizing the importance of doing so.

For the unit's culminating project, students designed their own survey questionnaires; determined the best sampling method to select respondents; collected, analyzed and interpreted the data; wrote up their results; created graphical displays and presented their findings to the class. At each stage, students needed to put critical thinking into action. In designing their questionnaires, they evaluated the wording of the questions for clarity and for potential bias. They determined what sampling method would be appropriate and had to employ it properly to collect data. They analyzed their findings and reported them in writing, orally and in graphical displays, maintaining vigilance against bias in all these tasks. Finally, students reflected on their work and noted what they might have done differently.

## Teacher Reflection:

Overall, the unit design and instructional methods worked well. To launch the unit, students read three statements involving statistics and were asked to identify the flaw. (Please see page 7). Talking through the scenarios in small groups was highly engaging for the students and primed the class to carefully analyze and interpret assertions based on data. In addition, user-friendly videos from the instructional series Against All Odds proved to be a particularly effective means of instruction as students were able to view professionals in action. This made the vocabulary come to life and helped the students to understand real-world connections and applications.

In retrospect, the expectation should have been made clear that all members of the group must take responsibility for all aspects of the project. This was not specified on the rubric, and as is sometimes the case in a group project, some members did more work than others, yet they all shared one grade. Next time, each student will turn in an individual draft of the written report for a grade. After receiving teacher feedback, group members will confer and write up their final analysis and reflection together. This approach will ensure that each student independently analyzes the data before working with the other members of his/her group. As part of this unit, Alicia had hoped to have time to teach the concept of margin or error, but had to postpone this due to schedule and calendar changes and challenges. The concept will still be taught, of course, and students will be able to calculate the margin of error for their own survey data as a postscript to the unit.

Previously, Alicia taught a different version of this unit. Improvements made this year included providing a detailed rubric to make expectations very clear. Most important was the sharpened focus on critical thinking, accomplished in part by expanding the use of articles for students to analyze throughout the unit, both independently and as a class. The addition of critical reading significantly enhanced the unit and helped students to bridge the gap from thinking critically about literature, history or general text to thinking critically about texts involving statistics and other numerical information. Going forward, we would provide even more opportunities to practice critical thinking by requiring a more formal write-up of students' analyses of the articles they bring to class each week in addition to having them prepare notes for discussion as they did this year.

Teaching this unit was especially enjoyable because of the students' excitement about their survey projects. They chose to research issues that they are invested in and have meaning for them. They had the freedom to design a survey about a topic that they really wanted to know about-something that directly affects them and the school community.

## Impact on Students:

The impact of this unit on the students can be measured in part by the strength of their work. All of them created well-designed questionnaires that yielded answers to their research questions. They demonstrated their understanding of key statistical concepts, sampling methods and bias. Evidence of critical thinking permeated their work as well as classroom discussions. One group even discussed the potential bias in the colors selected for their graphical display: They avoided using red or green as they felt that these colors suggest, respectively, a negative or positive result.

The final assignment of the unit was an individual reflection; several students wrote about their intention to follow up on their results. Two will meet with a student liaison committee in order to bring concerns about class placement issues to the attention of the administration. Another will incorporate what he learned about his peers' musical preferences in his plans for the next Kohelet Café performance.

Yet the impact of the unit that stands out above all else is the noticeable increase in students' confidence and their engagement with math-related material. They are a diverse group of learners, some of whom have struggled with math throughout their school years. To see them stand before the class and report their results with accuracy, confidence and excitement was both gratifying and inspiring. Moreover, students showed that they had learned to think critically about statistics by asking extremely thoughtful and perceptive questions about each other's work during the presentations. As these seniors go out into the world, their ability to think critically about claims based on statistics and to evaluate sources for reliability, validity and bias will stand them in good stead.

## Adapting the unit across disciplines:

This unit could easily be adapted for interdisciplinary integration and collaboration. The ability to read, write and think critically is, of course, valued across all disciplines. A history teacher might work in conjunction with a math teacher to teach a unit on survey research that focuses on political issues. The math teacher could teach the necessary statistics concepts and skills while the history teacher explains the relevant background and context needed to construct a meaningful survey in the subject area and to analyze the results from a historical perspective. Similarly, a science teacher could collaborate with both a math teacher and a physical education teacher to create a unit that includes surveying students about health-related subjects such as nutrition, sleep and exercise. An English teacher might take the collaboration in a different direction, perhaps by teaching the concept of an unreliable narrator alongside the math teacher's instruction on how to identify reliable, unbiased sources. Possibilities for integration with Judaic Studies include collaboration with a Hebrew language teacher to analyze opinion polls cited in Israeli newspapers.

## Adapting the unit for elementary and middle school students:

In addition to cross-disciplinary integration at the high school level, this unit can be adapted for K-8 students in various ways. It's never too early to begin developing critical thinking about math! Even the youngest students can be taught how to estimate, starting with developing a sense of the order of magnitude of an expected answer. For example, when they go to the supermarket, do the groceries cost about $\$ 1$, about $\$ 10$ or about $\$ 100$ ? Cultivating number sense is a first step in learning to analyze and interpret data. Learning to read and decipher various graphical presentations of information, such as pie charts and bar graphs, is also an important step that is generally taken in the early school years and then built upon in middle school. In addition, brief daily or weekly class polls, such as a "question of the week," could provide a myriad of possibilities for developing critical thinking skills. It is especially important to start this work in the primary grades in order to help students develop number sense and avoid developing a fear of math.

Students of all ages can also learn about bias through relatively simple lessons on the importance of considering perspective. Picture books can be quite useful in this regard; for example, Jon Scieszka's The True Story of the Three Little Pigs (Unabridged) tells the classic story from the wolf's point of view, thereby teaching a valuable and easily accessible lesson about perspective. Bringing in articles on current events is already part of the routine in many classrooms at all ages; this assignment could be readily adapted to focus periodically on articles that have a statistical or numerical component. Newspaper articles that present current events from different perspectives, using different - or the same - data to back up positions, would be of particular interest.

## Opening Activity for Survey Unit

Read each statement and find the flaw:

1. A new advertisement for Ben and Jerry's ice cream introduced in late May of last year resulted in a $30 \%$ increase in ice cream sales for the following three months. Thus, the advertisement was effective.
2. The more churches in a city, the more crime there is. Thus, churches lead to crime.
3. Seventy-five percent more interracial marriages are occurring this year than 25 years ago. Thus, our society accepts interracial marriages.

Source: http://onlinestatbook.com/2/introduction/what are.html

## Lesson Plan (2-3 days)

## Topic: Census and Sampling

Student objectives: (adapted from learner.org)
A. Know that a census is an attempt to enumerate the entire population; understand that it's needed to gather information about every subgroup of the population, but for information about the population as a whole, a sample is faster, cheaper, and at least as accurate (if not more accurate).
B. Recognize the difference between population and sample.
C. Recognize the strong bias in voluntary response samples, and generally in samples that result from human choice.
D. Understand what a simple random sample is; learn how to use a random digits table in order to select a simple random sample.

## Materials:

- Laptop or iPad
- Random digit table (provided)
- Unit 16 Against All Odds video and Guided Questions (learner.org)

Activity: (adapted from learner.org)
Go to the 2010 Census homepage. Then answer the following questions.

1. What is the current U.S. population? Notice that this number changes constantly.
2. Click the Population Finder. Select your state from the scroll-down menu to access the 2010 Demographic Profile for your state.
a. What was the population of your state in 2010?
b. What percentage of your state's population was male? Female?
c. Which was higher for your state, the percent under 18 or the percent 65 or over? (Give the percentages.)

## Practice:

1. Given a list of the senior class, use the random digit table to randomly select 5 seniors who will go to the administration to discuss changing the dress code policy.
2. Determine the population from the sample: A survey will be given to 100 students randomly selected from the (hypothetical) freshman class at Kohelet Yeshiva High School to gather information on their feelings regarding women reading the Megillah.
3. Determine the population from the sample: A doctor is concerned about the health of elementary school students at Torah Academy who have not had a flu shot during an outbreak of sickness in the school, so she examines 15 students to assess whether or not she thinks they might get the flu.
4. Determine the population from the sample: Fifty bottles of water were randomly selected from a large collection of bottles in a company's warehouse.

## Closure:

Have students look in the newspaper, or online, to find articles that mention the census in one form or another. Discuss articles in class.

## Ongoing during the unit:

Weekly articles brought in for critical analysis (every Friday). Each week, two to three articles are chosen and dissected as a class and evaluated for bias.
Assignment: Bring in an article that has statistics involved. Answer the following questions based on your article:

1. What is the topic being tested or researched?
2. What is the population?
3. What is the sample?
4. Do you think the research is valid? Why or why not?
5. Do you think the source is biased? Why or why not?

## Other topics taught during the unit:

- Sampling methods
- Data collection
- Questionnaire design
- Bias
- Measures of central tendency (review of prior knowledge: mean, median, mode, range)
- Graphical displays of data (including frequency distributions, histograms, stem and leaf plots, boxplots, pie charts and bar graphs)


# Kohelet Yeshiva High School <br> Statistics Survey Unit Project 

Kohelet students want chocolate pizza for lunch!
Kohelet students study for only five minutes before a test!

## Overview

Do you believe these statements? Do you want to find out what Kohelet students really want for lunch and how much they study, or do you have another burning question to which you seek the answer?

For this project, you will design a survey questionnaire to learn something about students at Kohelet. You will then develop a plan for selecting the students who will complete the survey. You will analyze the data, interpret and write up the results, and create a graphical display to clearly represent your data. You will then present your findings to the class.

## Phase 1

1. Choose 1 or 2 partners to work with for the project.
2. In your group, discuss what you'd like to know about the students at Kohelet (ex. study habits, opinion on a subject). Choose a topic to address and formulate a research question.
3. Create a series of questions designed to gather data that will enable you to answer your research question. Provide appropriate answer choices for each question.
4. Plan precisely how and to whom you will administer your survey. (You must include at least 25 students.)
5. Go forth and survey!

## Phase 2

1. Write a clear, detailed report of your results. Your report must include the following sections:

- Introduction-- What question are you hoping to answer?
- Sampling method-- Why did you choose this particular method?
- Data collection-- How did you implement the sampling method and gather data?
- Questionnaire design-- Explain the choice and wording of your questions and answer options.
- Analysis-- Carefully review your data and determine the answer to your research question. Discuss the margin of error.
- Reflection-- Think about the survey project process from start to finish. What do you believe you did well and what might you have done differently? What problems did you encounter and how could you fix them?

2. Create a neat and clear graphical display that avoids the types of bias we discussed in class.
3. Present your findings to the class and answer any questions.

## Kohelet Yeshiva High School

## Statistics: Survey Project Grading Rubric

Name: $\qquad$ Teacher: Ms. Sussman

## Title of project:

$\qquad$ Date: $\qquad$

|  | 1 | 2 | 3 | 4 | Points for each criterion |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Questionnaire design | Problems with questions, for example, two questions asked in one; one or more questions are difficult to understand or involve bias | Most questions are appropriate and are worded simply; one or more questions are difficult to understand or involve bias | Most questions are appropriate, thoughtfully and simply worded and easy to understand; all questions are free of bias | All questions are appropriate, thoughtfully and simply worded and easy to understand; all questions are free of bias |  |
| Sampling method and data collection | Inappropriate method AND errors in data collection | Inappropriate method OR errors in data collection | Appropriate method and proper data collection | Appropriate method and proper data collection; detailed explanation of reasoning behind sampling method and means of data collection |  |
| Written report | Results reported, but no evidence of analysis or reflection | Results reported with limited analysis and reflection | Results reported with clear, well written analysis and reflection | Results reported with clear, well written, thorough and sophisticated analysis and reflection | - |
| Graphical display | Problems with graphical display such as incorrect labels and/or titles; bias in display | One graphical display, neatly presented with proper labels and titles; bias in display | One graphical display, neatly presented with proper labels and titles; shows creativity; display is free of bias | More than one graphical display, neatly presented with proper labels and titles; shows creativity; displays are free of bias | - |
| Presentation | Basic presentation; some parts unclear; little creativity; questions are not answered | Clear presentation; some creativity; questions are answered | Clear, well planned, creative presentation; questions are answered | Clear, well planned, creative, highly engaging presentation; questions are answered | - |
|  |  |  |  | Total $\rightarrow$ |  |

## Samples of Student Work

## Class Placement Procedure

Link to questionnaire:
https://www.surveymonkey.com/r/Y9PRG8M
Below is an excerpt from the report written by this group, notable for the students' thoughtful consideration of ways that they might have improved the questionnaire and obtained more meaningful results.

Reflection:
Looking back, this project was informative, but also a learning process. There are several things we could have done differently. For example, we should have made all the questions required. This would prevent several students from skipping and skewing our results. Also the questions should not have been given to the freshman class. This is because they are new and have not yet been introduced to the school's process of class placement, which is probably why several students indicated that they did not know or were neutral to the process.

## Musical Preferences

Link to questionnaire:
https://www.surveymonkey.com/r/?sm=MFxQdN_2BUavLvDxqUQKp0eYLnrrRXOX_2BZxcs62MMb8mo_3D
One of several graphical displays designed by this group, the double bar graph below is particularly well suited to the data and goes beyond the project's requirements, demonstrating the students' creativity and initiative. They explained in their presentation that analyzing the results in this way provides a better overall sense of respondents' musical preferences.


