A Guide to Using Statistical Thinking in Science Fair Projects

from the Cleveland Chapter of the American Statistical Association

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Northeastern Ohio Science and Engineering Fair

Special Awards from the Cleveland Chapter of the American Statistical Association

Each year, the Cleveland Chapter of the American Statistical Association awards a number of prizes for the best uses of statistics in a science fair project at the Northeastern Ohio Science and Engineering Fair (NEOSEF). Our aim is to improve the scientific reasoning used by the students to reach their conclusions through proper use of statistical thinking. We believe that statistical thinking is inseparable from the scientific method. For example, every science project begins with a hypothesis. Statistical thinking helps define the hypothesis and provides the means for testing the hypothesis.

Reproducibility - One of the basic tenants of the scientific method is the idea of reproducibility: will the same results be seen when the experiments are repeated? It is for this reason that scientists replicate their experiments. That is, they run the same experiments a number of times to see if the results are reproducible. However, there will always be some variation whenever experiments are repeated, due to experimental error. Statistical thinking helps determine whether differences observed between groups (e.g., control and treatment) are real or are just due to experimental error.

Criteria for Awards

Statistical thinking does not necessarily require the use of statistical formulas or analysis - it only requires that the student recognizes and plans for the presence of variability. Because statistical thinking is useful in all fields of science, **every** science fair entry is evaluated by our panel of judges regardless of which category it is entered in.

There are two ways of using statistics in a science fair project:

- *Descriptive statistics* are ways of using statistics to describe data, through plots of data and calculating statistics like average and standard deviation.
- *Inferential statistics* are ways of inferring conclusions from the data. This includes "hypothesis tests." Inferential statistics and hypothesis tests are very powerful ways students can use to improve the quality of their science fair projects.

Descriptive statistics and inferential statistics are both important tools, and can be used in nearly any science fair project.

At a minimum, the Cleveland Chapter of ASA would like to see appropriate descriptive statistics used in all science fair entries. The use and understanding of appropriate inferential statistics would make stronger projects.

Prizes

Prizes awarded by the Cleveland Chapter of ASA have included Certificates of Award, cash prizes ranging from $25 up to $100, and copies of the book “Statistics: A Guide to the Unknown” by Tanur. In addition, teachers and advisors of winning students have received copies of the book “Exploring Data” by Landwehr and Watkins.

Who We Are

Our judges are members of the Cleveland Chapter of the ASA who volunteer their time to judge the science fair. They all either use statistics in their scientific work in Cleveland area industry and health care institutions, or teach in area colleges.

For More Information

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Visit the Cleveland Chapter ASA website at:
www.bio.ri.ccf.org/docs/ASA/k12.html#neosefl

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Your Science Fair Storyboard

by John Schollenberger

Let's start from the basic assumption that *of course* statistics are an integral part of any **data-based** science project: statistical methods (and thinking) are necessary for handling variation in the data, for reducing and summarizing data, for interpreting data and drawing appropriate conclusions, etc. But, how and where does one present these results? *Where* is in the report of course, but also on the storyboard. Further, especially on the storyboard, the presentation of the results should include more visuals (information graphics) and less text. Information graphics include statistical graphics plus flow charts, illustrations, maps, diagrams, photographs, and tables.

The purpose of the storyboard is to provide an easily-followed and quickly-comprehended overview—and, to attract interest and attention. One of the best ways to increase the speed and comprehension of the message is to replace long detailed paragraphs with graphics that communicate at a glance. The end result will be improved storyboards for the students, an easier-to-follow presentation of their research, and an easier job for science fair judges to judge the projects.

Instead of focusing on various statistical methods that might be useful for a science project, focus on improving storyboards (and reports) by using insightful statistical graphics—graphs that are easily comprehensible, that draw interest, and that quickly convince. Presenters too often try to post their entire report on a board, page by page. The details, however, should stay in the report. Only the main ideas, results, and conclusions, should be highlighted on the storyboard. Further, the easiest way to convey an idea quickly is with a visual: if it's real, a photograph; if it's abstract, an illustration or diagram; and if it's measurable, a chart or graph. Paragraphs of text should serve mainly as links between the information graphs, or to provide some secondary information.

Graphs vs. tables: Graphs don't convey information with the same precision as tables. Viewers of graphs, however, are more likely to be able to grasp the big picture, which is the intent of the storyboard. Graphs are more easily interpreted, more easily remembered, and more likely to be believed than less-visual alternatives for presenting the same information.

The **storyboard** cannot, and should not, attempt to provide all of the details—these should stay in the report. The purpose of the storyboard is to attract attention, and to provide an overview of the science project and the results of the research and study. It is not just an enlarged version of the report. However, since a storyboard viewer may wish to follow-up something in your project, relate your storyboard visuals to their place in the report.

Show, rather than tell. One of the best ways to increase the speed and comprehension of your message is to replace long detailed paragraphs with information graphics that communicate at a glance. Use paragraphs of text mainly as links to connect your information graphics, or to provide some additional detail about a preceding or forthcoming graphic. Always consider, however, whether the detail is necessary. It may be needed in the report, but is it necessary on the storyboard?

Flow charts can simplify even the most complicated procedures and sequences (e.g., the process flow of your own research). Flow charts permit you to visually indicate sequences, as well as important landmarks—points where decisions have to be made and the consequences of those decisions. In addition to adding visual interest, flow charts greatly reduce the amount of text required. Even for the report, if you are bogged down trying to describe a process or sequence, flow chart it and save the text for adding explanatory detail.

Use **organization charts** to describe relationships.

Use **time lines** to describe "history". Here history refers to the stages of the project or of the sequence of events or outcomes which occur as part of the experiment or research. That is, the project may be carried out in different stages or with measurements being taken at specific times, or there may be changes in what is being observed (e.g., life cycle of a virus of plant). History can also show both internal and external events. For example, it might show both the life of a virus plus the corresponding changes that take place in the body as it responds to infection.

Charts and graphs help readers and viewers quickly interpret the importance of numbers. A paragraph of numbers, no matter how well written, can rarely communicate relationships or trends as effectively as a good chart or graph.

Eliminate unnecessary detail from your charts and graphs. Often, for example, software programs' defaults add unnecessary background vertical and horizontal lines. Remember, exact numeric amounts and relationships are less important when your point is to emphasize trends, for instance.

Color: don't scatter it about; use it to highlight important information; use it to link sections together.

Steps in producing a storyboard.

1. **Plan your storyboard.** Inventory the text and graphic elements from the report that might be included. Identify the goals (the main message) and, based on that, try to envision the viewer's needs and expectations—what will the viewer need or expect to be able to understand your message or conclusions?

2. **Experiment with different layouts.** Does it all fit? If not, which parts are needed to convey the main message, to provide the big picture—and which provide secondary information that can be left to the report? Once you have a set of text and visuals that fit, check the flow. Are there any gaps?

Review the text portions again. Can some parts be replaced by a table or graphic? Review the graphics. Do they need to be simplified or changed for the storyboard? For example, for the storyboard, you might replace a stem-and-leaf plot in the report with a histogram.

3. **Produce a full-size version**. Do the pieces fit in a large enough size to be easily readable from four to six feet? Some secondary details may not need to be legible at that distance, but the important points should stand out—even from a distance. Indeed, make sure that your main message is the most prominent feature. Try to give your storyboard "aisle" appeal. Use visuals that will grab the viewers' attention and make them want to learn more about your project.

4. **Revise, revise, revise.** Again, experiment with alternative layouts. It is unlikely that the first version will be your final choice. When you see your storyboard at full size, you can usually identify many areas for improvement. Also, simplify as much as possible. As you review the text and graphics, constantly ask yourself:

•Is this word (or sentence) absolutely necessary?
•Can this paragraph be replaced by a list or table or a graphic?
•Can this title be rewritten to communicate the same idea in fewer words?
•Can this legend be removed and the parts labeled directly?

5. **Review the goals and expectations**. When you are satisfied with your revisions, check your storyboard in terms of your goals and viewer expectations from Step 1. If necessary, start again.

6. **Refine and fine tune**. Revise as necessary to enhance impact, to show the main conclusions and their justification, and to help the viewer move through the project.

> The graphics on a storyboard serve a different purpose than those in a report. Storyboard graphics are mainly for communicating the results and conclusions of an analysis, not for performing the analysis. Thus, they should be more like presentation graphics—intended to grab attention and, in the interest of simplicity and ease of comprehension, perhaps giving up some detail in order to get it.
>
> Taking this discussion a step further, consider the audience. The person passing by a storyboard or poster is perhaps not yet interested in the topic; for them the graphics need to have an impact in order to get their attention. The person reading the report, however, is already interested and is looking for details. Thus, exploratory graphs may be appropriate in the report, but probably not on the storyboard. For science projects the audience may be a little more technical or professional, but, at least for the storyboards, the message should be accessible to almost everyone. Again, it is the message that is important—if a simple graph does the job, then that should be sufficient.

Statistical Award Winners at the 1999 Northeastern **Ohio Science and Engineering Fair**

by Gerald Beck,
NEOSEF Special Awards Judging Organizer for ASA Cleveland Chapter

At the 1999 NEOSEF, nine projects were winners of special awards given by the Cleveland Chapter of the American Statistical Association. These projects were selected by our panel of judges from the over 400 projects entered in the NEOSEF.

Certificate of Award Winners

- "Sniff and Die: A Test of Inhalants" by Kirsten Hansen from Beaumont School in Cleveland Heights. This project compared *means taking into account variation*.
- "Results of a High School Questionnaire: Non-Traditional Occupations Impact on Relations" by Nida Degesys from Mayfield High School. This project summarized associations using *two-way frequency tables and chi-square tests*.
- "How Far Will Your Golf Ball Go?" by Robert DiMarco from St. Rita. This project compared the distance travelled of four types of golf balls using a home-built "driving" mechanism to apply uniform hits to the balls. The best ball was the Top Flight Strata as determined from
- *t tests* comparing the mean distances travelled of the three types of balls to the distance travelled by the a priori "best" ball.
- "Butane and Beyond" by McKensie Koss and Caroline O'Neill from St. Bernadette in Westlake. This joint project evaluated whether temperature affected the molecular mass of butane. Differences were shown by using *stem and leaf, and box plots*.

Certificate of Merit Winners

- "The Effects of Auditory Distractions and Age on Response Time" by Trevor McGrath from Mayfield High School. This project showed *scatter plots and regression lines* to examine the relationship between auditory distractions (such as loudness) and response time.
- "Rocky River Sedimentation" by Tom Blank from Lakewood High School.
- "The Impact of Different Number of Spiders on Prey Capture and Web Strength" by Elisa Jones of Hathaway Brown. This project used a clever design and summarized the data by *means and standard errors.*
- "The Bell Curve" by Hannah Hilow of Our Lady of Good Counsel. This project showed that dropping balls through a series of pins resulted in an approximate *"normal" distribution*.
- "Comparative Study of Body Mass Index of Female and Male Teens" by Hac Bui of Cleveland.

Statistical Award Winners at the 1998 Northeastern Ohio Science and Engineering Fair

by Gerald Beck,

NEOSEF Special Awards Judging Organizer for ASA Cleveland Chapter

At the 1998 NEOSEF, five projects were winners of special awards given by the Cleveland Chapter of the American Statistical Association. These projects were selected by our panel of judges from the 419 projects entered in the NEOSEF.

"Get the Lead Out" by Missy Blakely, a junior at Beaumont School in Cleveland Heights.
Missy's project examined the effect of lead on brain neurons in rats. The hypothesis was that lead inhibits neuronal differentiation causing impeded calcitronin gene-related peptide (CGRP). Brain neurons were exposed to lead concentrations of 25um and 50um and showed lower survival rates of CGRP percentiles compared with controls. ***Survival curves with standard deviations*** were shown. Missy worked on the project with Alison Hall, an Associate Professor at CWRU School of Medicine. Missy received a $25 cash award, the book "Statistics: A guide to the Unknown" by Tanur et al, and a Certificate of Merit. Her teacher, Ms. Kensig, received the book "Exploring Data" by Landwehr and Watkins. Missy Blakely was also the NEOSEF grand prize winner in the biological science division and competed in the International Science and Engineering Fair in Fort Worth, Texas.

"Does Balloon Color Affect Floating Time" by Kirsten Hansen an eighth grader at St. Dominic's School in Shaker Heights.
Kirsten's project compared four colors of balloons using five balloons of each color. Mean floating times were compared using a *one-way analysis of variance*. Significant differences were found with the colored balloons staying aloft longer than the white balloons. She received a $25 cash award, the Tanur book and a Certificate of Merit. Her teacher, Mrs. Turkell, was given the Exploring Data book.

"Which Type of Wood is Stronger" by Amanda Peck a tenth grader from Lakewood High School.
Amanda compared the breaking weight and flexibility of four types of wood: oak, poplar, pine and cedar using four samples of each. She first normalized the data to account for the different sizes of the samples and then compared the results by showing a *boxplot* for each type of wood. Oak and poplar had the best results. She received a $25 cash award, the Tanur book and a Certificate of Merit. Her teacher, Mrs. Lickly, received the Exploring Data book.

A Certificate of Award and the Tanur book were also given to two other students:

"Can the Addition of a Small Percentage of Rubber Change the Physical Characteristics of Asphalt" by Jennifer Nix, an eighth grader from Messiah Lutheran. Her experimental approach had good design features and used the data results to make reasonable comparisons.

Grant Meachem, a seventh grade student at Shaker Middle School studied "Creating Transparent Skin and Subcutaneous Tissue." His project used an evolutionary design where the next composition of Kraton polymers to test was determined from the results observed in the previous mixtures. The goal was to make a substance that could be used for modeling and practice of doing medical syringe injections in humans.

Statistical Award Winners at the 1997 Northeastern **Ohio Science and Engineering Fair**

by Gerald Beck,
NEOSEF Special Awards Judging Organizer for ASA Cleveland Chapter

The first prize went to Kevin Ostanek from Madison High School in the Biology 11-12 category for his project entitled "Gray tree frog research project." This study examined two species of gray tree frogs that look alike. When blood cell length and width were examined there was very good discrimination between the two species. A *Mann-Whitney Test* was used to compare the distributions of the two species. It was highly significant. A *cutpoint* was chosen to classify future frogs into the two species. There were only about 5 percent of the observations that overlapped in the two distributions. Kevin received $75 cash, Tanur's book and a Certificate of Award. Cohn's book was awarded to advisor Tim Matson at The Natural History Museum.

Cortrell Kinney from John Hay High School in Cleveland was awarded a Certificate of Award, a $50 cash award and Tanur's book for his project "Do estrogen and gibberellic acid affect plant growth?" His entry was also in the Biology 11-12 category. A Cohn book was awarded to his teacher, Mr. Jeffries. Cortrell's study compared the growth of plants given one of three treatments: control (no treatment), estrogen, and gibberellic acid. Plots were made of the plant height over time and the distance between major leaf nodes with *means and standard deviations* shown. This was one of the few projects recognizing variability. One group showed much more growth and the standard deviations did not overlap with those in the lower groups (gibberellic acid). The two lower groups (including the control) had much overlap in the standard deviations. Therefore, it was concluded that the gibberellic acid group did significantly better and the two lower groups were similar.

Jessica Blanton of Shaker Heights Middle School was also awarded a Certificate of Award, $50 cash award, and Tanur's book for her Biology 7-8 entry "The effects of detergent on DNA transfer to bacteria." Jessica compared the effectiveness of DNA transfer in bacteria in each of four groups by measuring the number of bacteria colonies formed to what was the expected level in a control group. She used a *Student's t-test* for each comparison and foundsignificance. She also showed the standard deviation of each group along with the mean.
Cohn's book was awarded to the teacher Ms. Loughler.

Certificates of Merit were also awarded to three other student:

"Achievement tests - the effects of ethnicity and environment," Gabriel Ling, Mayfield High School, BHS 9-10
Gabriels's entry compared SAT scores in 5 students of Asian ethnicity to 5 students of European ethnicity. He found higher mean scores in the Asian group. Also, he *correlated* a score of amount of pressure parents apply to students and the level of importance the students felt their parents placed on school to the SAT scores of both groups combined and found very low correlations and was able to interpret them properly.

"Which size bouncy ball bounces highest?" Amy Summers, Lakewood Junior High School, PMA 7-8.
Amy's entry had three balls of each of three sizes. Each size group's balls were of similar composition (but the compositions of the different sizes were different). She recorded the height each ball bounced after being dropped from the top of a refrigerator and compared the three size groups using the *mean, median, mode and range* of heights within each group.

"The speed of sound: constant? I think not," Jonathan Khoury, Mayfield High School, Math 9-10.
Jonathan's Physics and entry Jonathan measured the speed of sound by the time it takes to hear a board being hit with a hammer and seeing it being hit from a distance. Four values were recorded on each of four days where the outside temperature was different. Observations were done in Chagrin Valley Recreation area and excluded one observation as an outlier due to being more than 1.5 times the *interquartile range*. He showed that the observed relation of distance and time did not follow the expected quadratic relationship, probably due to experimental error in recording the measurements accurately (for example, precisely starting the stop watch when the board was hit with the hammer).