Cleveland Clinic

eXpressions™ MATH Where Research and Creativity Meet

Sample Interpretations of Student Research

The concept of art and literature being inspired by anything and everything is so familiar to us, we expect the youngest of children to understand it. When we challenge students to write a poem or create a sculpture based on scientific research, it does not seem out of the ordinary. We don't expect to have to explain the basic idea. Throughout history and prevalent in our modern society, artists of every type have no limits to the sources of their inspirations. No one would argue this.

However, simply stating that mathematics is a creative endeavor, and could be similarly inspired, can stop conversations and start debates. Therefore, as we embark on the eXpressions™ Math program, it is incumbent upon us to strongly make our case that mathematics is simply another path of expressing creativity. Just like other forms of expression, creativity can be inspired by anything – including scientific research – and the results can be clever, insightful, and even beautiful. That mathematics can also be useful undermines the "Art for its own sake" argument. Nevertheless, we will argue here with six examples that not only can mathematics be a creative outlet, but that because it involves a different way of thinking, it provides different inspirations that are no less worthy than poetry, painting, or dance – it is just less familiar to us in this context.

The research used in this example is a project called *Noise Levels in ECT and the Implications on Patient Care* by Nicole Kerling. Here are links to her poster and presentation:

Poster Presentation

In both of these resources, we learn that Nicole recorded sounds in the Post-Anesthesia Care Unit (PACU) for 4 weeks. She focused her research on patients receiving Electroconvulsive Therapy (ECT) that could be disrupted by noise. What follows are several sketches of approaches to using Nicole's research as an inspiration for a creative mathematical interpretation.

1.) Direct Mathematical Analysis

In the study, Nicole collected and presented a data set representing the raw number of sound events she recorded in each of 6 sound ranges. A student could directly analyze this mathematically by plotting the 6 points on a graph with the decibels on the x-axis and the frequency of occurrence on the y-axis. Students could then apply many different mathematical concepts to these points. Consider the following list:

i. Calculating the area under the curve using trapezoids.
ii. Calculating the area under the curve using trapezoids of smaller width.
iii. Calculating the area under the curve using calculus.
iv. Comparing the results in items i through iii.
v. Fitting a straight line and doing a least-squares difference for the points.
vi. Fitting polynomials of increasing degree to the data and calculating the reduction in the error of the estimate of each point as the polynomial's degree increases.

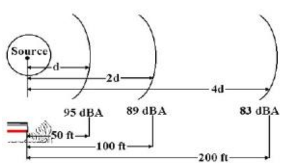
2.) Mathematical Exploration

What does it mean to be an outlier? There is only 1 sound in the 90 decibel range. From a statistical perspective, a project could look at whether this point is an outlier or not. Some tests for outliers are designed to identify a single outlier, other tests look at finding groups of outliers. Z-scores, Grubb's test, the Tietjen-Moore Test and others (found through student research) could be applied to the dataset given and the results presented. Depending on the results, follow-up analysis could be done to find a crossover point for each method. For example, suppose the Z-score indicates that the point is not an outlier; how much louder would it have to be to become an outlier? If another method suggests that is an outlier, how much softer would it have to be to lose that categorization? From here, students could explore in many different directions – looking at how the list would be impacted by additional data (louder or softer), what happens to the analysis if the outliers are removed from the data, or speculating on the effects of adopting the student researcher's recommendations on future collected data. To push even further, a student could leave the specifics of this study and explore the concept of an outlier in general.

3.) Mathematical Extrapolation

As indicated in the diagram, the loudness of a sound decreases the further away from the source it is observed. By using the formulas relating the decrease in decibels with the increase in distance, students could calculate how far the source of the sounds would have to be for all of them to be within the recommended range for a PACU in the day and night. Explaining the relationship between loudness and distance through the formula and giving diagrams (the clipboard would have had to been dropped X distance away – and give a specific tangible reference point. This could lead very nicely into consideration and explanation of exponential functions and asymptotes.

Distance Attenuation of Noise Levels



http://www.schoolphysics.co.uk/age16-19/Sound/text/Sound_levels_and_distance/index.html

4.) Fanciful Mathematical Speculation

In Nicole's study, she recorded 234 sounds in 6 different categories. She provided the exact number of sounds in each category. She does not provide any information about the order she recorded the sounds. A student interested in combinatorics could calculate how many different possible orderings of the sounds could have resulted in this data. The student could then speculate on different aspects of their proposed orders – how many of the orderings are symmetric? How many are in ascending or descending order? In how many of them are all the sounds for a given range in sequence? In how many of these orderings is the 90-decibel sound preceded by a soft or loud sound making it seem relatively louder or softer? Note that these questions have no bearing on the reality of the study, but use the study to leap in a particular mathematical direction and open up an avenue of speculation that is mathematically interesting.

5.) Mathematical Creation

A key aspect of this study is the relative proportion of the sounds in the different ranges. These proportions represent a probability of a sound being in a given range. Using a random number generator and a collection of sounds (homemade, smartphone app, online tool, etc.), a student could recreate a representation of the range and frequency of sounds collected in the PACU. From this, they could create a sound recording and experiment with making the resulting sounds more or less appealing. Students could analyze both the probability and sound wave aspects of this idea.

6.) Mathematical Research

Students could set up their own experiment inspired by this study. Using one of the tools mentioned in #5, the student could provide sounds to volunteers (through headphones, in a dark quiet room, etc.) and ask the volunteers to estimate the decibel range of the sounds that were used in the original study. The student could record the actual sounds and the volunteer's estimates and determine the granularity of the human perception of sound as compared with the ranges used in the study. From this, the student could critique Nicole's selected ranges as being too broad, too narrow, or acceptable, and, if appropriate, propose a better set of ranges.

7.) Mathematical Wandering

Students could ignore the vast majority of the study and focus on a small aspect of it. This project does not have a lot of visual components, so for illustrative purposes, we'll select the pie chart as the small aspect to focus on. Separating the chart from all meaning in the study, we have 6 shapes of 6 different colors that can be arranged to form a circle. This represents the most compact shape that can be formed. How can we re-arrange the shapes to produce the largest contiguous shape? If we draw a bounding box around these 2 shapes, what is the ratio of the largest to the smallest? Are there interesting geometric arrangements of the shapes that have unusual properties?