**Dice, Histograms & Probability**

**Teacher Notes**

**Description**

Students roll provided dice (> 1 die per roll) and record the resulting individual values as well as the sum of the values. They create histograms of the data.

Students develop insight into the concept of “degrees of freedom” by rolling differing numbers of dice and noting how the histograms change.

Students can extend the activity by using a spreadsheet to simulate the pseudo-random numbers they would obtain with dice rolls.

Teachers can further extend the activity by provided loaded dice; sufficiently large numbers of rolls with these can create a “bump” in the histogram.

**Standards Addressed**

*Next Generation Science Standards*

Science and Engineering Practices

4. Analyzing and interpreting data

5. Using mathematics and computational thinking

7. Engaging in arguments from evidence

Crosscutting Concepts

1. Patterns

*Common Core Literacy Standards*

Reading

9-12.7 Translate quantitative or technical information . . .

*Common Core Mathematics Standards*

MP5. Use appropriate tools strategically.

MP6. Attend to precision.

Enduring Understanding

Data can be analyzed more effectively when properly organized; charts and histograms provide methods of looking for trends in the data that a list of random numbers cannot provide.

**Learning Objectives**

Students will know and be able to:

* Precisely record simple observations.
* Create and interpret a histogram.
* Describe the degrees of freedom (variability) present in the system under study

**Prior Knowledge**

Students must be able to keep careful records of observations and sum integers.

**Background Material**A fair die has an equal probability of producing any of the available numbers. Histograms of the individual rolls shouldn’t show any features at all—they should be flat.

Degrees of freedom can be thought of as the number of independent pieces of information needed to find the answer minus the number of calculations needed to arrive at the answer. In this case, the number of die minus one since the interesting representation is the sum of all of the rolls for that student. This is a definition used in statistics. For biologists and chemists, molecular bonds have three degrees of freedom to undergo thermal vibrations: they can stretch, they can twist and they can flex. Each of those vibrational modes corresponds to a different energy, which means when you expose these molecules to infrared light, they will absorb light at three distinct wavelengths per bond; furthermore, a C=O bond would have different resonances from a C-H or N-H bond. Thus infrared spectroscopy becomes an important tool for chemists trying to determine the structure of a molecule. For physicist, degrees of freedom is an important topic in quantum mechanics and specifically in particle physics when the discussion turns to the many pathways for particle decay.

Students will see a peak in the histogram of sums of the rolled die, (e.g., 3 d6s (die 6 sided). The location of the peak depends two things: how many rolls that you combine, and the number of sides on the rolled dice. There are three ways to roll a 10 when rolling two d6: 6+4, 4+6, and 5+5. There are 27 ways to roll a 10 when rolling *three* d6! *The peak of the histogram appears at the sum that can be most easily created.*

If only six sided dice are used, the degrees of freedom are number of dice minus one (N-1). If the dice used have different numbers of sides, then the degrees of freedom are number of dice minus 2 (N-2).

**Implementation**

We do not provide a student handout with this activity.

* Provide students with sets of similar dice. All groups should have the same number and type of dice if you wish to pool individual or group data into a larger, shared set.
* Ask the students to record their dice rolls and draw histograms of their data. Each group will make two histograms. A single histogram of all of the single roll values for their own data. The group will also make a histogram of the total of dice thrown for each roll.
* A spreadsheet can be used to combine the class data and generate one histogram with a large data set.

**Extensions:**

1.Many spreadsheets have a facility for creating random numbers. You might consider asking your students to do this assignment on a spreadsheet.

2. Provide the students with a mixture of die types and repeat the experiment.

**Assessment**

Have students display their group histograms around the room. Ask them to note differences in the histograms. An interesting technique is to ask students to confer in their group, present their answers on a white board and share their ideas and answers with the class.

You might ask students questions such as:

* What number appeared most often in the rolls? Discuss the reasons for this.
* What would happen to the histogram if there were twice as many dice rolls recorded on it?
* Make a spreadsheet of the combined class data to form a new histogram to test the prediction.
* Write a paragraph length conclusion based on the results. Be sure to include a discussion of the effects of ‘degrees of freedom’ or ‘variability’ in the explanation.

Extension questions:

* Predict the effect of using a mixture of dice types. What will the new total histogram look like.
* Test the prediction.
* Write a conclusion.