PowerPoint Notes on Numbers in Science

Slide 1

Two good sources for background information:
http://www.nhn.ou.edu/~johnson/Education/Juniorlab/Error-SigFig/SigFiginError-043.pdf
http://www.physics.unc.edu/~deardorf/uncertainty/UNCguide.html for background information on uncertainty

Slide 2

Slide 3

Point out in each of the photos how an estimate would come into play. In the baby bottle, the 1's place of mL-cc will be an estimate, the 0.1 place of the US and UK fluid ounce would be an estimate. In the Vernier calipers, the tenths place of mm is an estimate. Students may think that a digital meter has no estimate, but remind them that at some value the last digit will flip between two adjacent values. If we assume that it is not happening here, we can conclude that the 0.0001 place is an estimate, since it is not provided.
Appropriate measurements might be: 199 mL, 21.0 mm, 6.9 UK fl oz, 6.8 US fl oz, 5.783 mm, 0.385 V

It might be interesting to point out the difference in the US and UK systems of fluid ounces. This comes from the fact that the US first adopted (during Colonial times) the British wine gallon (about 3.79 L), and the UK chose in 1824 to adopt the ale gallon (about 4.54 L). The British gallon consists of 160 fluid ounces, while the American consists of 128 fluid ounces. So, both the unit of the ounce and the size of the gallon are different in the two countries, illustrating the ambiguity in the non-metric system.

It might also make sense to discuss a Vernier scale and how to read it.

Slide 4

Some textbooks and scientists opt to interpret measurements with less associated uncertainty. That is, 68.5 kg is implicitly 68.5 ± 0.05 kg, or the value is known to be between 68.45 and 68.55. The exact rules used are, in the opinion of the author, less important than the idea that a properly reported measurement conveys something about the uncertainty associated with it.

Slide 5

This slide is intended to cover the basics of significant figures. Teachers should supplement or skip as they need. The emphasis of this lesson is on the nature of uncertainty in measurements rather than a specific set of rules for dealing with sig figs.
These measurements are astronomically significant; the first is the mass of the sun, the second is the distance to the moon, the third is the age of the solar system, the fourth is the speed of light, the fifth is the number of planets in the solar system (post-Pluto's removal), and the last is the exact length of a year. This may generate some conversation about related side topics, such as missions to the Moon (the distance is actually much better known than this measurement implies, but the distance changes sufficiently that this is generally true), the big bang, the definition of the speed of light, the rejection of Pluto as a planet, and leap years.

Slide 6

Slide 7

In the second graph, error bars have been added. They are very small and hard to see in the horizontal axis, since they are only 1 mL and the scale is in 50 mL. They are more noticeable in the vertical direction.

Slide 8

Point out the lack of exactness in these reported numbers. Here, the author emphasizes the uncertainty in the measurement of 40,000 anti-protons (probably ± 1000) and 1000 Kelvin (probably ± 100 K, although there is some ambiguity) by using the word about. 10 % can be interpreted as 10 ± 1%, while 9 K could be thought of as 9 ± 1 K as well. In some cases, words do a better job communicating the essence of a number than the numbers themselves do, as in the expression “probably cold enough.”

Slide 9

Although the value is reported as 40 light years (which would imply 40 ± 10 ly), astronomers actually know the distance to 55 Cancri A very well. Wikipedia reports its distance as 40.3 ± 0.4 light years

Slide 10

Tracks are reported often as “400 m” even though their actual distance is actually known to within fractions of a meter. This is especially true for tracks used for high level competition. Food labels report nutrition information with an uncertainty of ±20%. This is particularly relevant for diabetics and anyone else who depends on accurate information about their intake. As a result, many diabetics try to avoid high carb foods, simply because the uncertainty is smaller for smaller total values. That is, it’s not a “low carb” diet that is necessary, but a “low uncertainty” diet. In the label shown, the 25 g of carbs labeled is not 25 ± 1 g as you might assume but instead 25 ± 5 g.

Slide 11

Slide 12

Slide 13

An important point to note is that a “successful” experiment is often considered one in which the random error (at reasonable levels) is larger than the systematic error. For example, the maker of a meter stick must be confident in his placement of the markings to much less than one millimeter, since he is marking millimeters on the device.

Slide 14

Example 1: the measurement is consistent with the accepted value.
Example 2: the labeled focal length is 150 mm ± 10 mm, so it is consistent with the measured value.
Example 3: the observation is not consistent with the measured values. It is brighter than anticipated, which could be due to a supernova you just observed occurring in the galaxy. Lucky you!

Slide 15

Slide 16

Slide 17

Slide 18

Slide 19

Encourage students to explain why the spread of the distribution is equivalent to the spread of the arrows, and why the distance of the distribution from the "true value" is equivalent to the distance of the arrows from the bulls eye.

Slide 20

This is the main idea of standard deviation that all physics students encountering large data sets should be familiar with. More mathematics follows on the next two slides, but this is central to what many high school science students should grasp.

Slide 21

This may or may not be necessary to include, depending on the mathematical sophistication of your classes.

Slide 22

This may not be necessary for many classes, but it is included for those wishing to see a worked example for standard deviation.
Note that the "stdev" function in Excel calculates the standard deviation as if the data is a sample of the whole, and therefore uses N-1 instead of N in the formula. "StdevP" uses the formula given.

Slide 23

The nature of these graphs is very closely drawn from Mindy Lekberg's work with the MOSAIC data in her classroom.

Slide 24

Solicit student feedback for an answer of 4 for the last question. If you use clickers, this would be a great chance to solicit feedback.

Slide 25

Illustrate here the reduction in error bars arising from greater number of observations.

Slide 26

This slide is intended to show the advantage of averaging to discern a weak signal above the noise. The x-axis shows frequency, with the 0.00 frequency corresponding to 11.07 GHz, or the center of the rotational transition of ozone that we are measuring.