Sources of Error and Writing Conclusions Review Packet
Homework 3.16

This packet was designed to help you complete your exhibition. Most of this is a review of the work you did last year in 6th grade science.

**NO HW PASS ALLOWED**

Sources of Error:
Directions: Analyzing the following graphic organizer about sources of error. Make sure you understand what the terms: “sources of error,” “experimental error” and “human error” mean. Then answer the questions that follow.

**Sources of Error:**
Limitations/ flaws that negatively affect the results of an experiment

**Experimental (Equipment) Error:**
Mistakes that are "out of the experimenter’s control"
Ex: equipment failure, lack of sterile lab environment

**Human Error:**
Mistakes made by the experimenter
Ex: measured something incorrectly, put the wrong amount of a substance in a beaker

1. A student accidentally touches the cotton swab on a surface besides the one being tested. This is: (circle one)
   a. Experimental (equipment) error
   b. Human error

2. The batch of nutrient agar that was ordered for the Petri dishes did not have enough nutrients for bacteria to grow. This is: (circle one)
   a. Experimental (equipment) error
   b. Human error

3. The incubator breaks down and as a result the petri dishes are not warm. This is: (circle one)
   a. Experimental (equipment) error
   b. Human error

4. A student incorrectly counts the square units filled with bacteria while collecting data. This is: (circle one)
   a. Experimental (equipment) error
   b. Human error

Writing Conclusions:
Directions: Read the following pages. As you read, underline main ideas and annotate. Make sure you are familiar with how to write a conclusion for an experiment.
Drawing Conclusions Based on Data

What is a Conclusion?

At the end of an experiment, scientists analyze their data to draw conclusions about their variables. The conclusion is a detailed answer to the original testable question – it includes a claim about the effect of each "treatment" on the dependent variable, and uses quantitative data as evidence to support this claim. For example, if scientists conduct an experiment to investigate the testable question, "How do different fertilizers affect plant growth?", the scientists should be able to analyze their plant height data from each setup, and to use this data as evidence to make claims about which fertilizer worked best. Their description of these claims, along with the quantitative evidence, is called a conclusion.

What types of quantitative data do we use to draw conclusions? Usually, students are taught to draw conclusions based on only mean data. However, when scientists draw conclusions or make claims based on their data, they always consider the MEAN data AND the RAW DATA. Raw data is data from ALL individual trials or test subjects. By examining raw data, scientists can see how the spread and consistency of the data might affect their conclusion. In this class, we will analyze data the way scientists do – by examining both mean data AND raw data.

Why is it important to look at spread and consistency in the raw data, in addition to analyzing mean data? When a data set has outliers, or when the data has a large spread, the mean is NOT a good representative of the data. As a result, it is impossible to draw conclusions based on the mean data alone. In order to state a claim, scientists must compare the mean data from different setups AND consider the consistency and spread in the raw data. Only then can scientists make a data-based claim in response to the testable question. Below you will find steps and tips for writing a strong conclusion.

How to Write a Conclusion

STEPS TO FOLLOW:

STEP #1: Compare the MEANS and make a claim about the effect of each 'treatment', compared to the control.

Compare the mean of each experimental group to the mean of the control group. Based on ONLY the means, make a claim describing how each treatment seemed to affect the dependent variable. Your claim should be the answer to the testable question!

STEP #2: Describe any observations about the RAW DATA that might support or weaken your claim from STEP #1.

Does your raw data provide additional information that might affect the claim you made based on the means alone? Perhaps the means were not good representatives of the data! In this section of the conclusion, include any information about consistency, spread, range, and outliers that might strengthen or weaken your claim from STEP #1. For example, use the 'Finger Test' to identify OVERLAP between the raw data in the different setups! How much does the raw data from each group overlap, if at all? What does this overlap mean? And are there outliers that affected the mean data described in STEP #1? This information will be used in STEP #3 to make revisions to the claim you made in STEP #1.

STEP #3: Revise your claim if necessary, or restate your original claim.

Make a NEW and REVISED claim about the effect of each treatment on the dependent variable, now that you have ALSO considered the raw data. If your claim does not change,
Writing a Conclusion

MODEL

Below is a conclusion based on the data from the experiment testing the effect of different fertilizers on plant height. The data table and graph are shown below, followed by the conclusion.

<table>
<thead>
<tr>
<th>Fertilizer Type</th>
<th>Plant 1</th>
<th>Plant 2</th>
<th>Plant 3</th>
<th>Plant 4</th>
<th>Plant 5</th>
<th>Plant 6</th>
<th>Plant 7</th>
<th>Plant 8</th>
<th>Plant 9</th>
<th>Plant 10</th>
<th>MEAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>35</td>
<td>23</td>
<td>22</td>
<td>30</td>
<td>26</td>
<td>24</td>
<td>23</td>
<td>27</td>
<td>23</td>
<td>23</td>
<td>23.4</td>
</tr>
<tr>
<td>MiracleGro</td>
<td>56</td>
<td>54</td>
<td>56</td>
<td>55</td>
<td>60</td>
<td>53</td>
<td>58</td>
<td>59</td>
<td>57</td>
<td>57.3</td>
<td></td>
</tr>
</tbody>
</table>

The Effect of Fertilizer on Plant Growth

**STEP #1**: Compare the MEANS and make a claim about the effect of each ‘treatment’, compared to the control.

Based on the means for each setup, it seems that MiracleGro causes plants to grow taller, making it an effective fertilizer. The data shows that the mean plant height for the MiracleGro plants was 57.2 cm, compared to only 23.9 cm for the control plants, which were given only water. MiracleGro seems to more than double plant height!

**STEP #2**: Describe any observations about the RAW DATA that might support or weaken your claim from STEP #1.

The raw data confirms (agree with the idea) that the MiracleGro likely increases plant height. This is because ALL MiracleGro plants grew taller than ALL control plants. The MiracleGro plants consistently grew to heights within the range of 54 – 62 cm, compared to the control plants that only grew to heights between 20 – 27 cm.

**STEP #3**: Revise your claim if necessary, or restate your original claim.

In conclusion, the data suggests that MiracleGro is effective in increasing plant height, compared to plants given only water.
WRITING TIPS

When writing a conclusion, follow the important tips below:

1. **Use language of uncertainty**: Remember, one experiment does NOT 'prove' anything. All data must be reproduced by other scientists multiple times in order for the scientific community to be confident in a particular conclusion. We must convey our uncertainty when we write our conclusions:

<table>
<thead>
<tr>
<th>USE this language</th>
<th>STAY AWAY from this language</th>
</tr>
</thead>
<tbody>
<tr>
<td>The data suggests...</td>
<td>Unclear</td>
</tr>
<tr>
<td>It seems that...</td>
<td>Uncertain</td>
</tr>
<tr>
<td>Might</td>
<td>Inconclusive</td>
</tr>
<tr>
<td>Likely</td>
<td>Definitely</td>
</tr>
<tr>
<td>Probably</td>
<td></td>
</tr>
<tr>
<td>Somewhat</td>
<td></td>
</tr>
<tr>
<td>Fairy</td>
<td></td>
</tr>
</tbody>
</table>

2. **Use quantitative data**: Your data (NUMBERS!) is the evidence that supports your conclusion or claim! Use as much quantitative data as possible! Ways you might use quantitative data when writing your conclusion:
   - Compare the actual **means** from your data. You can even calculate the **difference** between the means of different groups!
   - Calculate and identify the **range** in the data when describing the spread of the data. Identify specific outliers!
   - **AVOID NAKED NUMBERS**!

3. **Use data analysis vocabulary throughout your writing when relevant**:

   consistent/repeatable spread range outlier mean representative