Ocean Waves and Graphs

A group of science students was on a kayaking trip in Puget Sound. They noticed that different waves seemed to travel at different speeds. One student described some waves as traveling “over the top” of other waves. Another student said that to her it looked more like the waves that she called “slow rollers” scooted underneath the others. The students decided to see whether they could find a pattern in the speeds of these waves.

The students thought that the easiest things for them to measure would be the size and speed of the waves. They decided that they wanted to study some waves that looked different from each other and that it would take a lot of teamwork to get the job done. So with some students paddling, some holding boats still, and others making measurements, they measured the height, length, and speed of several waves. Measurements they made of eight waves are shown below.

<table>
<thead>
<tr>
<th>Height (ft)</th>
<th>Length (ft)</th>
<th>Speed (ft/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.3</td>
<td>0.8</td>
<td>5.1</td>
</tr>
<tr>
<td>0.5</td>
<td>0.5</td>
<td>4.0</td>
</tr>
<tr>
<td>0.8</td>
<td>9.5</td>
<td>17.4</td>
</tr>
<tr>
<td>1.0</td>
<td>4.9</td>
<td>12.5</td>
</tr>
<tr>
<td>1.2</td>
<td>1.9</td>
<td>7.8</td>
</tr>
<tr>
<td>1.3</td>
<td>3.6</td>
<td>10.7</td>
</tr>
<tr>
<td>1.7</td>
<td>1.2</td>
<td>6.2</td>
</tr>
<tr>
<td>1.9</td>
<td>6.3</td>
<td>14.2</td>
</tr>
</tbody>
</table>

So what do we learn from this? Does the height of the wave influence the speed? Does the length influence the speed? Does the height influence the length? The jumble of numbers above is hard to interpret. Your mission is to make graphs from this data and see if you can find patterns that help us learn about wave speeds.

Since the students were interested in wave speed, we’ll call that our “responding variable” or “dependent variable.” We have two choices for “manipulated” or
“independent” variable. We don’t know which variable makes the most sense so we’ll have to try both.

It is customary for scientists to put the dependent (or responding) variable on the vertical or “y” axis of a graph. The independent (or manipulated) variable goes on the horizontal or “x” axis of the graph. We often use the language that the dependent variable is plotted “as a function of” the independent variable. In math classes we often think of “y” as a function of “x”. We’ll make two graphs (you can use two sheets of graph paper). On each graph, plot the “responding variable” on the vertical axis and the “manipulated variable” on the horizontal axis as in the diagrams below.

<table>
<thead>
<tr>
<th>A generic graph showing the orientations of dependent and independent variables. A real graph would have better labels to tell us what is being displayed. The meaning of a graph should be clear to all who read it.</th>
<th>A graph showing the amount that would have to be spent to purchase different quantities of eggs. To be useful, this graph should also have a title and scales (numbers of eggs and units of money) on each axis.</th>
</tr>
</thead>
</table>

Now get some graph paper and make a couple of graphs. Make a different graph for each choice of independent variable. Make your graphs large enough so that they are easy to read (you can use one sheet for each graph if you like).

While making your graphs, check them over to see if you remembered to include all of the features of a good graph. Here are some things a good graph should always have:

- Do your graphs have titles at the top so that a reader would immediately know what the graph is about?
- Do the axes of the graphs have labels (on the left and on the bottom) so that the reader knows what is being graphed “as a function of” what?
- Do the axes have “scales” shown by tick marks labeled by numbers with units? The units can be shown in the label (as in “length of wave in feet”) or they can be shown along the axes (as in “1 foot… 2 feet… 3 feet…”, etc.).
Once you have two graphs, compare your graphs with those of your classmates and try answering the following questions.

- Scientists often test their “ideas” or “models” by making predictions. Based on your graphs, predict the speed of a wave that is 0.7 ft high and 2.8 feet long.

- Which graph(s) did you use for your prediction? Why? Explain your reasoning.

- Scientists are often looking for “correlations” or “connections” between things. Which would you say is more closely correlated with the speed of a wave, the height or the length? Explain your reasoning.

- Be honest. Was the answer to the previous question as obvious when you first looked at the table of data on page 1? Why or why not?
End of Module Questions:

1. A student at the Knotvery Sound School used a microphone to record sounds made by an acoustic guitar. She plucked different strings and she used a video camera to measure how much the plucked string was vibrating (in millimeters). The microphone automatically measured the frequency (or note) in hertz (Hz) and the volume (or loudness) in decibels (dB). The data is shown in the table below:

<table>
<thead>
<tr>
<th>Vibration (mm)</th>
<th>Frequency (Hz)</th>
<th>Volume (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.3</td>
<td>520</td>
<td>42</td>
</tr>
<tr>
<td>0.8</td>
<td>440</td>
<td>38</td>
</tr>
<tr>
<td>0.3</td>
<td>590</td>
<td>30</td>
</tr>
<tr>
<td>0.5</td>
<td>780</td>
<td>34</td>
</tr>
<tr>
<td>2.1</td>
<td>700</td>
<td>46</td>
</tr>
</tbody>
</table>

So the student wants to know: what does the size of the vibration influence? Does it influence the frequency (which is the same as the note)? Does it influence the volume (which is the same as the loudness)? Or both? Make a couple of graphs to help the student sort this out.

2. According to a popular web search engine, the following is one of the most frequently viewed graphs on the Internet. It was apparently created by a humorist named Bobby Henderson who noticed (he claims) that as global warming worsened as pirate populations decreased [editor’s note: global warming is a serious issue but we don’t have much faith in Henderson’s research]. Pretend for a moment that Henderson’s data is reliable. Take a look at the graph (which looks remarkably Excel-ish) and suggest a few ways it could be improved.
3. Here is another graph taken from the Internet. In the interest of protecting the privacy of the people who posted it, we aren’t going to tell you anything about it. Simply comment on the graph. List some aspects of the graph that could stand improvement. How many can you find?
4. According to the Australian website “Census at School” the following table shows real data of student heights, right foot lengths, and belly button heights (all in units of centimeters). Investigate the correlations. Is belly button height a good predictor of height? Is total height closely correlated with the length of the right foot? (And when dealing with this much data, what’s the most reasonable way of dealing with the data?)

<table>
<thead>
<tr>
<th>Total Height (cm)</th>
<th>Right Foot (cm)</th>
<th>Belly Button Height (cm)</th>
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<tbody>
<tr>
<td>131</td>
<td>20</td>
<td>80</td>
</tr>
<tr>
<td>162</td>
<td>22</td>
<td>92</td>
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<tr>
<td>151</td>
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<td>157</td>
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<td>154</td>
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<td>172</td>
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<td>102</td>
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<td>166</td>
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<td>156</td>
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