Wiggle Matching – David Little and Marie Breitenstein

Purpose
The aim of the lesson is to introduce children to the role computational thinking plays in asking scientific questions, and specifically in how it helps scientists to date soil samples using Carbon 14.

Overview
This purpose is achieved through the specific example of wiggle-matching. Wiggle-matching is the processes of matching variations in the estimates of radioactive carbon dates across multiple sources to get a more accurate picture of the data. This process is distilled into a simple pattern matching activity for the students. After a review of radioactive dating and a description of the activity, students spend most of the lesson wiggle-matching and filling out the accompanying worksheet. A final wrap up asks students to think about how scientists would wiggle-match on a large data set.

Student Outcomes
Students will be able to explain the similarities in the patterns of radioactive carbon when comparing soil and tree data.
Students will be able to describe the process of wiggle-matching.
Students will be able to describe how wiggle-matching helps us find more precise dates of the earth.
Students will be able to describe what an algorithm is.

Time
Approximately two to three periods, or about 80-120 minutes, depending on how much review is necessary and whether students are required to cut up the 3x3 sheets of graphs.

Level
6-7th grade. The activity could easily be expanded or elaborated upon to provide enough substance for an older class.

Materials and Tools
Provided with this lesson are the worksheet, a soil data graph, and a tree data graph. These are the graphs students will be asked to matched. A computer projector may be of utility in explaining an example of wiggle matching but is not necessary. A solution set is provided as well.

Preparation
Ideally the 3x3 sheets of soil and tree data will be cut out before hand (so that each piece has a single one of the 9 graphs on it).

Prerequisites
Students should have been taught about absolute and relative dating of rocks. The estimated time for the lesson assumes some review of this material will occur, and part of the worksheet includes review questions. It is not essential that student understand the particular exponential nature of radioactive decay: only a simple qualitative understanding should be required (the longer something is in the earth the less radioactive carbon there is).

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Teaching Notes

Background: Scientists use a process of "wiggle-matching" to help accurately date peat-moss which is in turn used to help develop an accurate record of the past climate and develop better climate models. Estimates of absolute dates from Carbon-14 from peat-moss are not very accurate. Wiggle-matching takes advantage of the fact that the amount of Carbon-14 in the air varies considerably over the years. This variation will lead to the same patterns of variation visible in different data sets. If the variations are the same in two sets of data it is a good guess that these two sets of data were recorded at the same time. Thus, by corroborating the peat-moss variations with the variations in the Carbon-14 record gathered from tree rings more accurate dates for the peat moss can be found. More information about this method can be found in the following reference:

Blaauw, M., Van Geel, B., Mauquoy, D., & Van Der Plicht, J. (2004). Carbon-14 wiggle-match dating of peat deposits: advantages and limitations. *Journal of Quaternary Science*, *19*(2), 177–181. doi:10.1002/jqs.810

What students need to understand: Since the goal of the lesson is to help students better understand the role of computational methods in asking scientific questions it is not important that students understand all the details of the wiggle-matching method. The lesson has been boiled down to the essence of what wiggle matching is: students are asked to match the patterns of wiggles in one data set to another and to think about how they actually did this pattern matching.

Lesson Introduction: After a introduction to what the lesson will cover and a read-through of the basic scenario at the top of the worksheet, begin by reviewing relative and absolute dating (with Carbon-14) of layers of the earth with students. The first page of the worksheet has a number of questions students should be able to answer after a brief lecture covering both the reviewed material and the concepts behind the lesson. Walk through the example of wiggle matching with students on the second page (possibly while displaying the example on a projector). Make sure students understand that each data set they are matching represents a record of Carbon-14 levels in the air at different times in the past. Explain that the Soil and Tree 1 represent Carbon-14 levels in the shallowest layers and Soil and Tree 9 represent these levels for the deepest (oldest) layers. Emphasize to students that the kind of puzzle solving they're doing to find these lines is the kind of thinking scientists have to employ to make sense of their data.

Wiggle-matching Activity: Break students into groups and give each group the 9 graphs of soil and tree data. Have them line up the tree data in a row, and the soil data in a row, and have them mark lines 19 and 20 in the Soil data as the example shows. Ask students to find and mark as many of the remaining lines as they can.

Differentiation: As faster students begin to complete the activity, ask them to begin to work on the remainder of the work sheet. Students will notice that they cannot find all of the lines (c.f. the Soil Solution pdf). Challenge students to think about why there would be missing soil data: why would soil be missing, but not tree rings? Ideally effects on soil such as erosion have been discussed in class before. Once these are addressed you can ask students to begin to fill out the algorithm section of the worksheet.

Algorithm: Once most students are finished with the activity ask them to think carefully about what they did. Tell them to write this down in clear explicit steps. Explain that this is what is called an algorithm. Ask any students that know the word to define it, and make sure that a good definition is arrived at. One such definition would be: "A process or set of rules to be followed in calculations or other problem-solving operations". If there is time, ask students to explain the steps they used to another group, and ask the other group to say whether they think they could follow the directions. In my experience, many students will try to write the entire description down in one step. Emphasize to students that they should break things down into smaller steps than they would normally. A useful example of breaking things down: "rather than saying, drink the milk, you could break this down and say 'grab the milk with your hand, bring it to your mouth, pour the milk into your mouth, and then swallow it'".

Closing: See the assessment below for details of the follow-up discussion. Generally the final page of the worksheet should be finished after the group discussion, or as homework.

Assessment

The attached worksheet provides the students with questions to consider throughout the lesson. The wrap-up period of the lesson should include a class discussion that touches on the following questions. This is usually discussed before students fill out the final page of the worksheet.

1. With your partner, compare the soil and tree wiggle data. Brainstorm some observations about your comparisons, i.e. similarities, differences, gaps in data.

There are many things students might say here, and all of these observations can be praised. The key observation for purposes of this discussion however is the large gap in the soil data: lines 10-13 are missing from the tree data. Ask students why there might be this missing gap in the data (plausible explanations include erosion and human error).

2. Before we had done the wiggle-matching could we have known about the missing data. Why or why not? Do you think wiggle-matching is useful for scientists learning about the soil?

Students are likely to get creative and think of other ways the gaps in the data might be found, and these should of course be praised, but the point of the question is to get student thinking about what purpose the wiggle-matching serves and why scientists would want to do it. There is no right answer, but push students to think about the utility of wiggle-matching.

3. The more data a scientist has, the more confident you can be of your conclusions. Keeping this in mind, how would you wiggle match thousands of wiggle graphs?

The resulting discussion of possible solutions should include a mention of the fact that scientist can use the algorithm like the one each group developed on page 2 to tell a computer how to wiggle-match. The computer could then solve the problem for many graphs. However, before this could be done, you would still have to think about this problem very carefully so you can write a good algorithm. Emphasize to the students that the thinking they are doing during the wiggle-matching activity is a lot like the kind of problem solving a scientist has to do to design a good algorithm that a computer could use to solve this problem with a large data set.