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ABSTRACT

Graphing is a common and powerful symbol system for representing concrete data. Yet research has shown that students often have graphical misconceptions about how graphs are related to the concrete event. Currently, the Technical Education Research Center (TERC) is developing microcomputer-based laboratories (MBL) science units that use probes to gather data on such physical phenomena as motion, heat and temperature, and response time. With these probes attached to a microcomputer, real time graphs can be displayed of data as they are being collected. The research component of the project is looking at graphing misconceptions (such as confusing the graph of an event with a picture of the event) and how MBL can help students to learn graphing skills. Preliminary results suggest that MBLs do help in improving graphing skills. Attributes of the MBL science laboratories that seem important in this include: (1) the grounding of the graphical representation in the concrete action of the students; (2) the inclusion of different ways of experiencing the material (visual, kinesthetic, and analytic); and (3) the fast feedback that allows students to immediately relate the graph to the event. (JN)

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GRAPHING MISCONCEPTIONS AND POSSIBLE REMEDIES USING MICROCOMPUTER-BASED LABS

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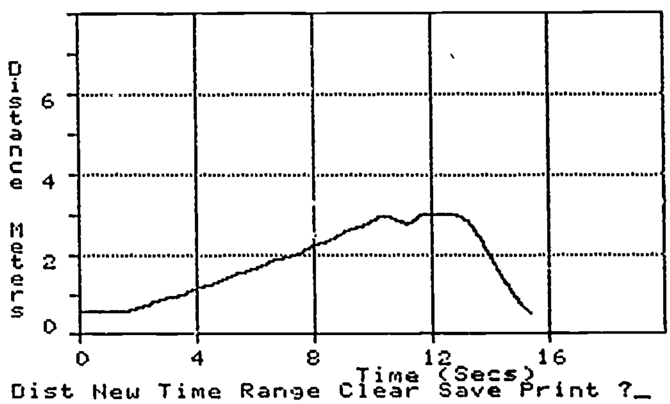
GRAPHING MISCONCEPTIONS AND POSSIBLE REMEDIES
USING MICROCOMPUTER BASED LABS

Graphing is a common and powerful symbol system for representing concrete data. Yet research has shown that students often have graphical misconceptions about how graphs are related to the concrete event. This paper looks at some of these misconceptions and at how using microcomputer-based laboratories (MBL) can provide a way of clarifying them.

Microcomputer-based Labs (MBL) are a powerful new science learning tool. Under an NSF grant, TERC is currently developing MBL science units that use probes to gather data on physical phenomena such as motion, heat and temperature, and response time. With these probes attached to a microcomputer, real time graphs can be displayed of the data as it is being collected. The research component of the project is looking at graphing misconceptions and how MBL can help students to learn graphing skills.

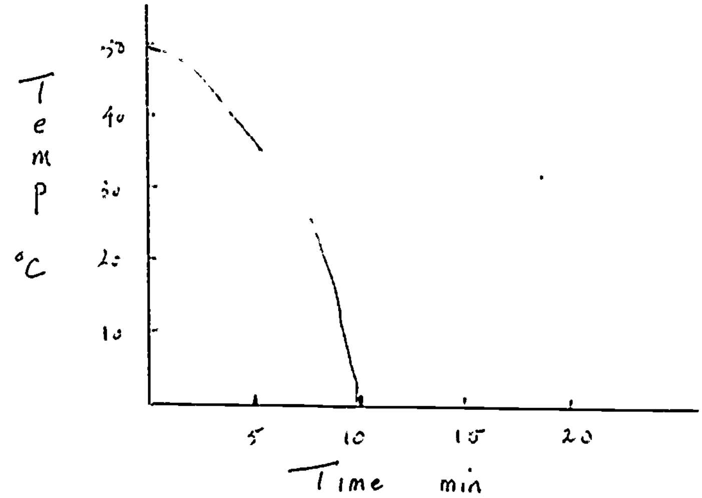
Example 1: Here is a graph of a person who walked away slowly and then walked back, faster. The graph was made using our TERC motion detector connected to an Apple microcomputer. The detector is the sonic probe that is used as the rangefinder on Polaroid cameras. The graph is drawn on the screen as the person moves, thus giving a real time graph of the person's motion. One student held the sonic distance probe and operated the keyboard, and another student did the walking.



Picking out a third student, I asked, "Where did she turn around?" He looked confused, tried to answer, and then said, "I don't understand the graph. Why doesn't it come back?"

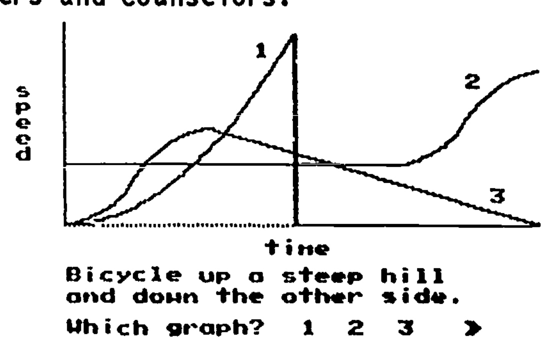
If the walker came back to her starting place, why didn't the graph come back to its starting place?

Example 2: Here is a student's sketch of the graph from a heat and temperature experiment. The experiment was to place the temperature probe in hot water, start the graph, and after 10 seconds pour in an equal amount of cold water.



These two examples show the confusion that middle school students can have about understanding the time axis. In the motion case, the person walking gets further away and then closer, but time marches on. Distance is reversible; time is not. In the hot and cold water example, the water starts hot and ends up cold, and the graph starts at the y-axis and ends at the x-axis (that is not the actual graph that comes up on the screen, but it is the student's sketch of that screen graph.) Hot and cold are the two variables, and the student does not see time as a variable at all.

One way of analysing these misconceptions is to think of students as confusing a graph of an event with a picture of the event. Here is another example of the graph as picture misconception, this time taken from a workshop for teachers and counselors.



from Interpreting Graphs, by Sharon Dugdale and David Kibbey.

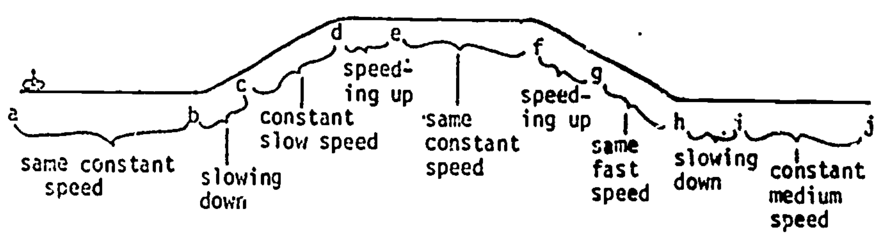
The person at the keyboard was about to select 3 as the correct answer. One of her partners pointed out that the vertical axis was speed, not distance. She pondered the graph for another minute and then said, "well, I still think it's 3."

As part of the graphing research study at TERC, we have asked students the opposite question. Instead of here is the graph what is the event, we explain the event and ask for a sketch of the graph.

A cyclist rides along and over a hill. She applies a constant pressure to the pedals.

a) For each part of the road (a-b, b-c, c-d, d-e, e-f), look at the words below the picture that say what is happening to her speed. (For example: speed constant, speeding up, slowing down.)

b) As you look at each part of the picture, draw the shape of a graph of her speed versus her distance along the road. (Don't give actual numbers, just draw the shape of the graph.)



Not only did students tend to draw a graph that is a picture of going up hill and then down the other side, but upon discussing their graph with the researcher, they usually stayed fixed on their interpretation. As other researchers have shown (Clement; McKenzie & Padilla) this picture/graph misconception is common to college age students as well; in other words, it is not simply a developmental cognitive issue.

Some people have criticised the idea of using microcomputers and probes to teach graphing concepts. "Well" they say, "if you take an abstract representation of a physical event (the graph) and use a black box connected to more black boxes to display it (the microcompter and screen with the probes plugged into the micro), then what do you expect? You are compounding the problem, not clarifying the concepts." This does not fit, however, with some of our other experiences with students.

In a fourth grade class using temperature probes, a phase change experiment was set up using moth flakes to show what happens as the para-chlorobenzine cools from a liquid state to a solid state.

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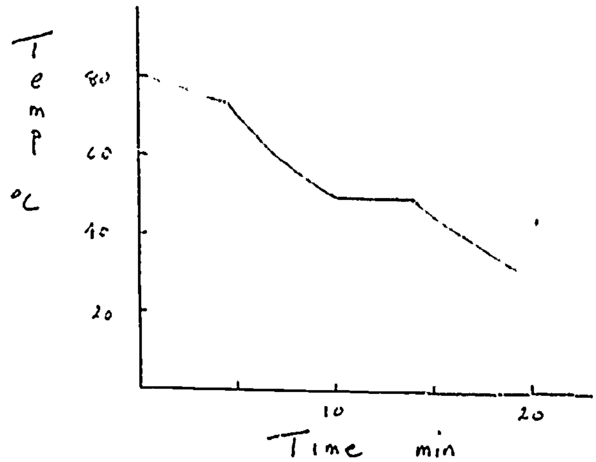


Everyone watched the experiment as the liquid moth flakes cooled, crystalized, and cooled. The time scale had been set at 20 minutes, and at the end of that time the moth flakes were still hotter than room temperature. We asked the students a series of questions about the graph that had just been produced.

1. What was the initial temperature of the moth flakes?

2. What happened here? (pointing to the change of slope when we put the test tube into a beaker of cold water to speed up the cooling).

3. At what time did the liquid start to crystalize? ... at what temperature?

4. What would the graph look like if you extend it for another 20 minutes?

With the exception of question #4, these students knew exactly what the graph was showing and answered the questions confidently. On the last question, some of the students extended the cooling curve down to the x-axis (0 degrees) but some correctly drew it approaching room temperature. This question about the final equilibrium temperature is a subtle one, however. In general these fourth graders thoroughly understood the graph and its relationship to the phase change experiment.

Our graphing research plan consists of two stages. The first phase consisted of interviewing students in order to identify the types of graphing misconceptions commonly held. These interviews were conducted one-on-one and took 30 to 40 minutes each. During the interviews the students were asked to answer a series of graph questions and to talk about their choices. Where graphing misconceptions were demonstrated, the interviewer asked more questions to see if the student would change his or her answer after further discussion. This research was completed during the 1984-85 school year. A total of twenty five students were interviewed.

The second phase of the research involves using the probes to see if the MBL activities contribute to understanding graph conncepts. This starts with our longitudinal field test of five of the MBL science units in the 1985-86 school year and will continue during successive years. Our intuition is that the concrete nature of the MBL activities will make the graphs completely understandable. Our experience during the first year, however, indicates it is not an instant, magicial remedy. Students do understand graphs better, but they are also still confused by some of the subtler aspects of the graphs. By explicitly teaching about these subtler properties in the context of the graphs the students generate, it is hoped that these confusions will also disappear.

One way to understand what is meant by subtler graphing concepts is to consider levels or orders of questions about graphs. First order questions involve direct reading of values from the axes of the graph, such as what was the temperature at time 7.5 seconds? Students at the middle school level are generally able to correctly get such explicit data from graphs. Second order questions involve interpretation of properties of the graph such as slope, the significance of positive and negative values, and intercepts with the axes or with another graph. Examples of second order questions include:

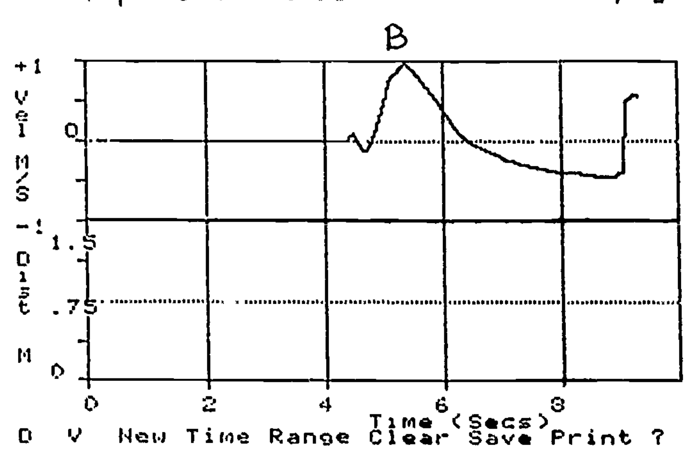
1. For a cooling curve experiment, when was the cooling fastest?

2. For a distance graph of a person walking a round trip, when was the person standing still?

3. For a velocity graph of a toy cart doing a round trip on an inclined plane, when did the cart turn around? ... or when did the initial push of the cart up the incline stop?

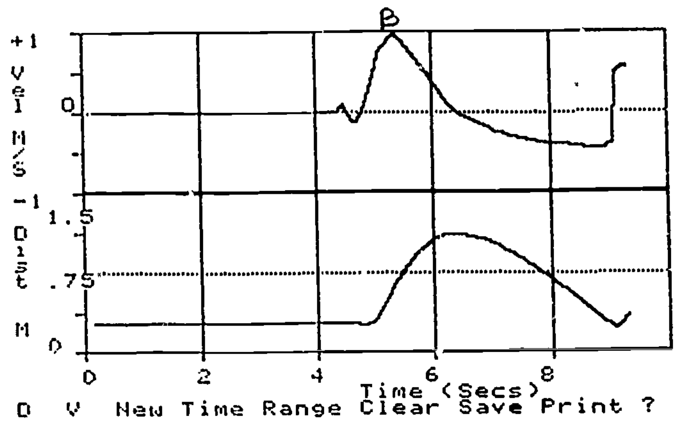
Instead of looking statically at individual points on the graph, these questions require looking dynamically. You need to consider the whole graph and how it changes and what these changes mean in terms of the physical events being graphed.

Here is an example of a second order confusion that we often encounter in classes using the motion unit. One of the final activities involves a toy cart on an inclined plane. The cart is given an initial push up the incline resulting in a round trip up the ramp and back down again. Here is a real time velocity graph for such a trip.



After students have completed several trials, we ask them to point out on the graph where the cart turned around. The picture is so compelling; many students choose (in fact, many people, teachers included) B as the point where the cart reaches the top of the ramp and starts back down.

Given the real time velocity graph, the computer can then produce a distance graph of the event.



When a student has incorrectly identified the turn around point on the velocity graph, a dialogue such as the following typically ensues.

teacher: Can you point to the place on the distance graph where the cart turned around?

(students vary on their response to this, some choosing the correct place, and some choosing a point beneath B, their incorrect choice on the velocity graph.)

teacher: When was the cart furthest away?

student: At the top of the ramp.

teacher: Is that where the cart turns around?

student: Yes.

teacher: Where is that on the distance graph?

(students now choose the correct point on the distance graph.)

teacher: And where on the velocity graph is the point where the cart turned around?

(students who initially made the incorrect velocity graph selection remain steadfast in their misinterpretation.)

teacher: How fast is the cart going at the top of the ramp?

student: It is turning around.

teacher: So how fast is it going then?

(if students have trouble with this question, it helps to say that the cart stops at the top of the ramp.)

student: The velocity is zero.

At this point students recognize the points on the two graphs that correspond to the cart turning around at the top of the ramp. Further, the point where the velocity is zero and where the distance is greatest are lined up vertically, meaning they both occured at the same time, which of course they did.

Next question: What is happening at point B on the velocity graph?

Talking explicitly about the graph and these second order properties is one of the ways we hope to clarify these second order concepts. Another way is by getting students to act out a graph. An example of this again comes from the motion unit. The students are given a picture of a person graph and asked to reproduce the graph, using the motion detector.

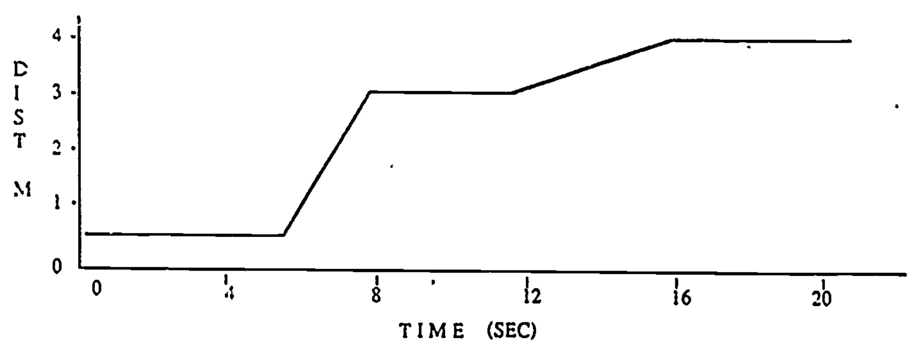
7. Consider the graph below.

   a) Move so the computer draws this graph.

   b) Work as a team. Get the times right. Get the distances right.

   c) Each person should take a turn.

   d) Have the teacher sign below when your group makes a good copy.



In solving problems such as this, students often use a choreography like process. One student takes the role of explaining how a second student should move in order to reproduce the graph. After critiquing their performance, they typically try again, often switching roles.

Further research will see whether we are right in believing that graphing skills are improved through using MBL. If the learning is substantiated, attributes of the MBL science units that seem important in contributing to this include:

a) The grounding of the graphical representation in the concrete actions of the students.

b) The inclusion of different ways of experiencing the material: visual, kinesthetic, and analytic.

c) The fast feedback that allows students to immediately relate the graph to the event.

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