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14.0.C Hands-on Visualizing Thermal Eqilibrium

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When you mix things that have different temperatures, what is the temperature of the mixture?

Materials: thermometers, digital or liquid (use same type)
clear plastic cups marked at 40, 60, 80 mL
reservoirs of "cold" and "hot" water

Instructions: Manager – read the top line of each procedure step to the group.
Recorder – record information in recorder report for steps 2 and 4

1. Three experiments, all with the same procedure. Only the volumes change. Do one experiment at a time. Sequence doesn't matter. Use the water reservoirs.

First experiment:	40 mL of hot	and 80 mL of cold
Second:	60 mL of hot	and 60 mL of cold
Third:	80 mL of hot	and 40 mL of cold

2. BEFORE YOU DO ANYTHING, MAKE PREDICTIONS. Write them down.
   Assume that the HOT water has a temperature of 40 degrees C.
   Assume that the COLD water has a temperature of 10 degrees C.
   Predict a value for the temperature AFTER mixing for each set of volumes.
   Report your predictions and reasons to the instructor.

3. Now, do the experiments. Do one at a time. Move quickly.
   Think about best point in time to record temperatures.
   Measure out the volumes.
   Measure and record the temperature of the hot and cold water.
   [The actual temperatures won't be 10 ^{o}C or 40 ^{o}C].

4. Pour one container into the other. (Doesn't matter which.)
   Measure the temperature right away.
   Record it.

Displaying results: Manager – ask someone to read out loud, quickly steps 1-3

1. Get a piece of poster graph paper. Draw a vertical temperature line for your range of temperatures.

2. For each experiment:
   Place a RED-ish X on the line at the temperature of your HOT water.
   Place a BLUE-ish X on the line at the temperature of your COLD water.
   Place a BLACK X on the line at the temperature of the mixture.

3. Draw a red-ish arrow from the RED X to the BLACK X.
   Draw a blue-ish arrow from the BLUE X to the BLACK X.
   The arrows show what the temperatures have changed from and to.

4. Stick your poster up on the wall near you. Names on it.

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Making sense of the results (all goes into Recorder Report):

1. Compare your predictions with the results. Are they consistent? That suggests something about your intuitive sense of the process.

2. In a single concise sentence, express how the starting volumes affect the location of the final temperature relative to the two initial temperatures.

3. Someone asks: "Why isn't the temperature of the mixture always half-way between the two starting temperatures? That's what you get when you average things, right?" What is your response to that?

4. What happened to the hot water? What happened to the cold water?

5. If you haven't yet thought about what's happening at the molecular level, now is the time. Develop an explanation for the observations that is based on molecules.

6. How is heat related to all of this?

7. Check in with your instructor at this point to share your thinking on these questions.

Your instructor will give you a challenge to consider at this point.

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When the group is ready, ask:
In the mixture, are all the water molecules now at the same temperature, or are they still at different temperatures but the thermometer senses the average?

Create a possible procedure by which you could explore this, and share it with me.

They have to develop the idea that they have to keep the water from mixing (in order to monitor temp) but still let heat move. Make them work for it. Let their thinking evolve.

Once they seem to be on this conceptual path, present them with equipment:
an aluminum can inside a coffee mug
Tell them to develop a specific procedure, and then clear it with instructor

Challenge their intended data acquisition
ask how they intend to present their results, and is that fully convincing concerning the original question.
Push them to "plot T vs time for both containers"

Once they latch on to that, give them the go ahead to collect data, and then get it onto graph and onto the wall. This will spur other groups.

They can use the same volumes (choices on board; make each group different)
(These will fit in the containers and give good temp measurements).
Make a prediction as you did last time:
Will it be the same as with direct mixing?
What will the end result be?
What do you expect to see happen?

If they mess up, it's easy to restart the experiment. No experiment lasts more than 5-10 minutes.

Plot on large graph paper. Seeing things go up on the wall will spur others.
Once their graph is up, ask each person in the group to describe what is happening.
Then, say:
We need to call this something.
Let's call it "coming to thermal equilibrium"

Continue questioning:
Why don't you get to thermal equilibrium right away?
Try to elicit the idea about "heat moving"
What do you mean by "moving"? What is moving? How can you tell?
What could you investigate that might tell you about this "moving"?
What determined the speed of movement? What determines the direction?

Speed is a key word to hold in reserve because it hints that one might think about what it takes to slow or to speed up the movement of heat.

Direction is also key – because no distinction to this point has been made as to whether it is "cold" that is moving or "heat" that is moving.

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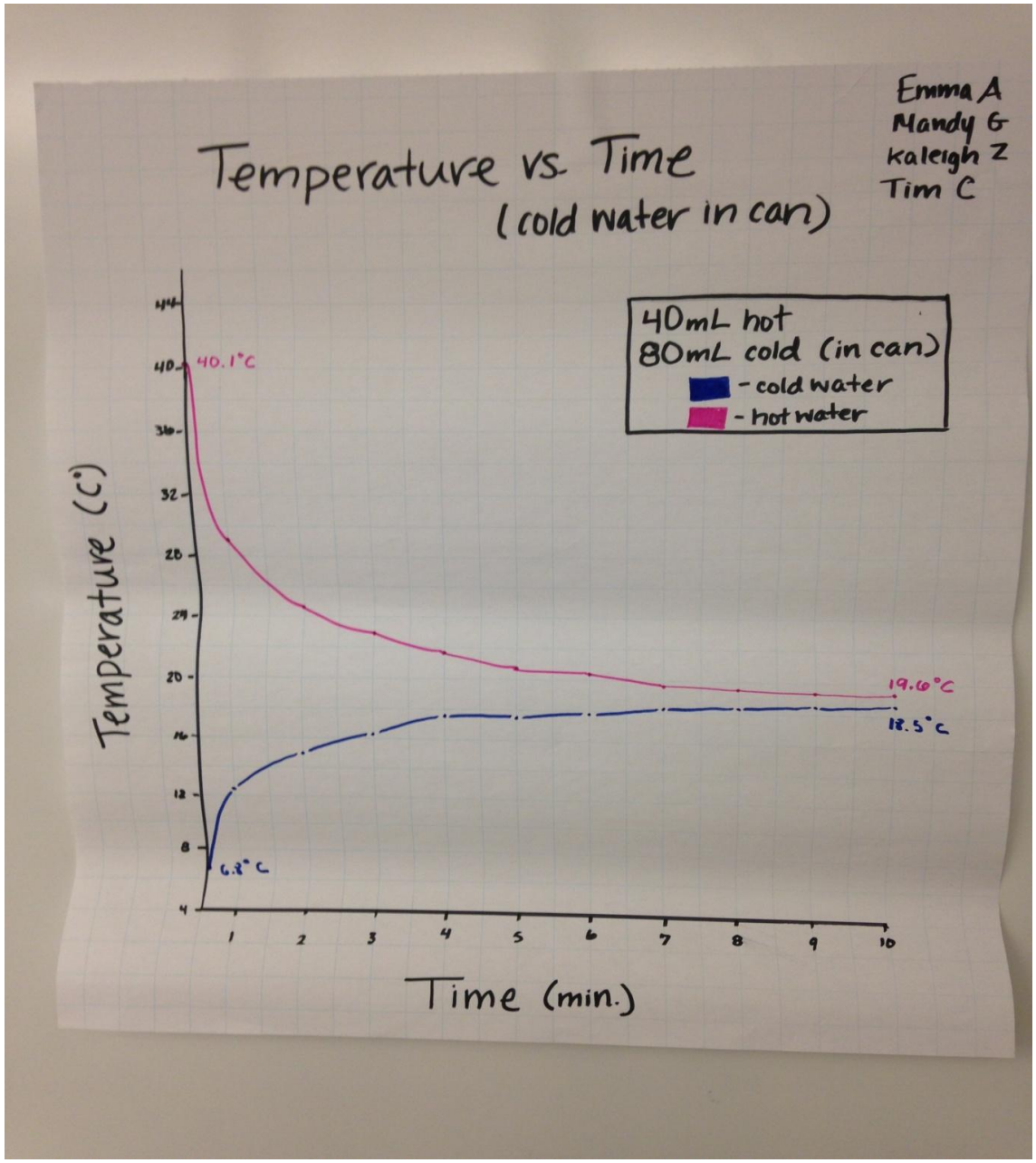

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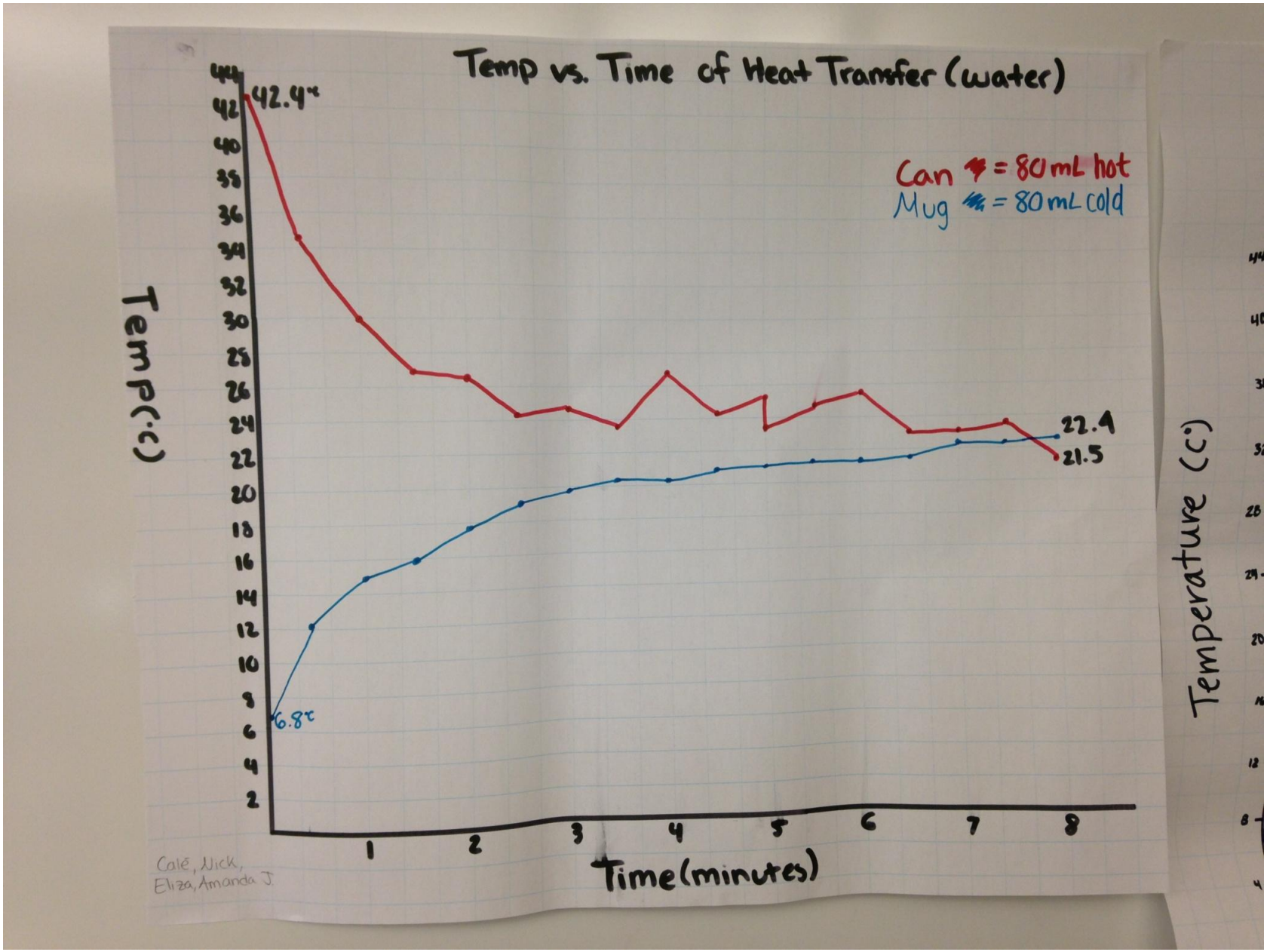

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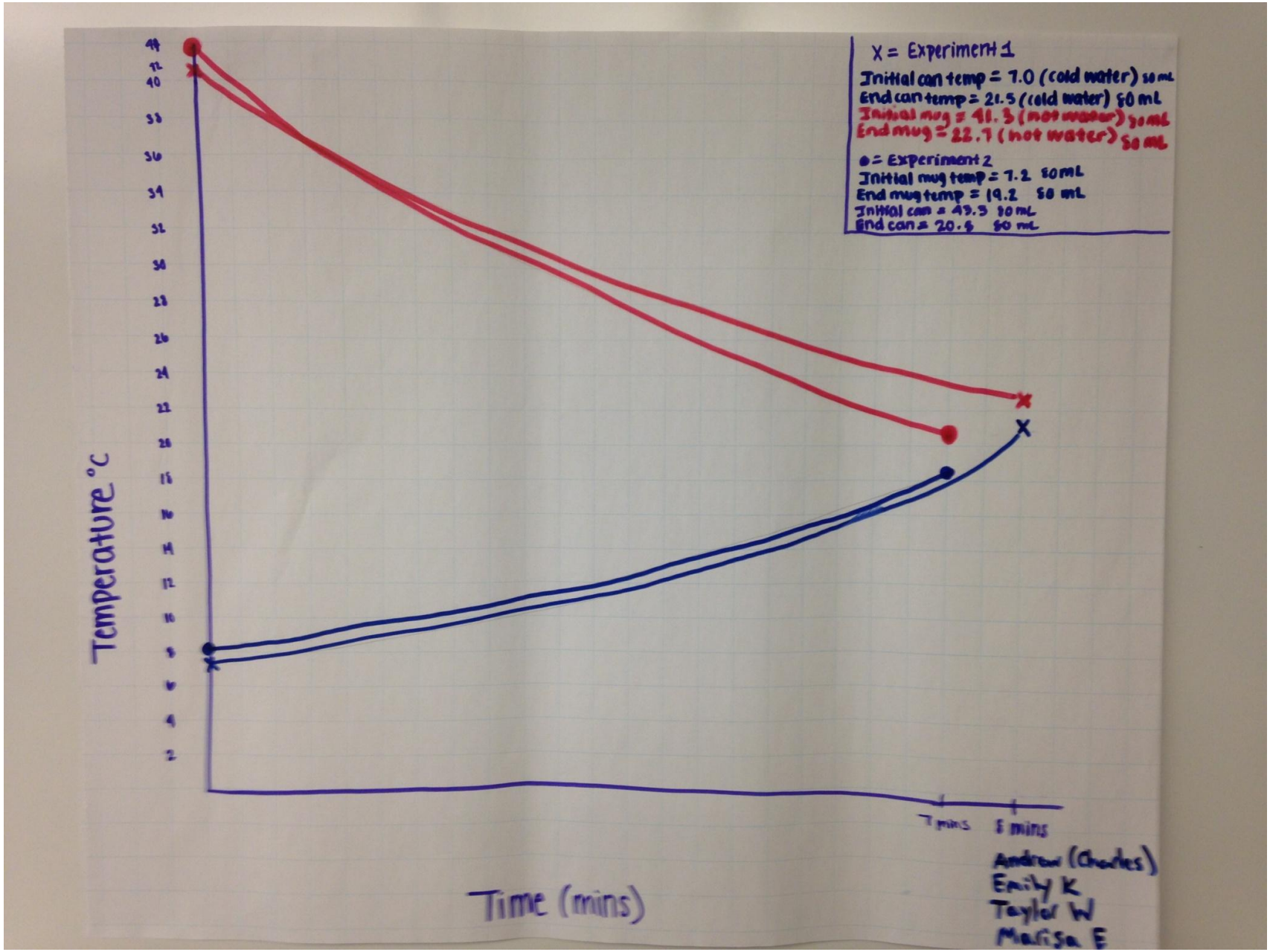

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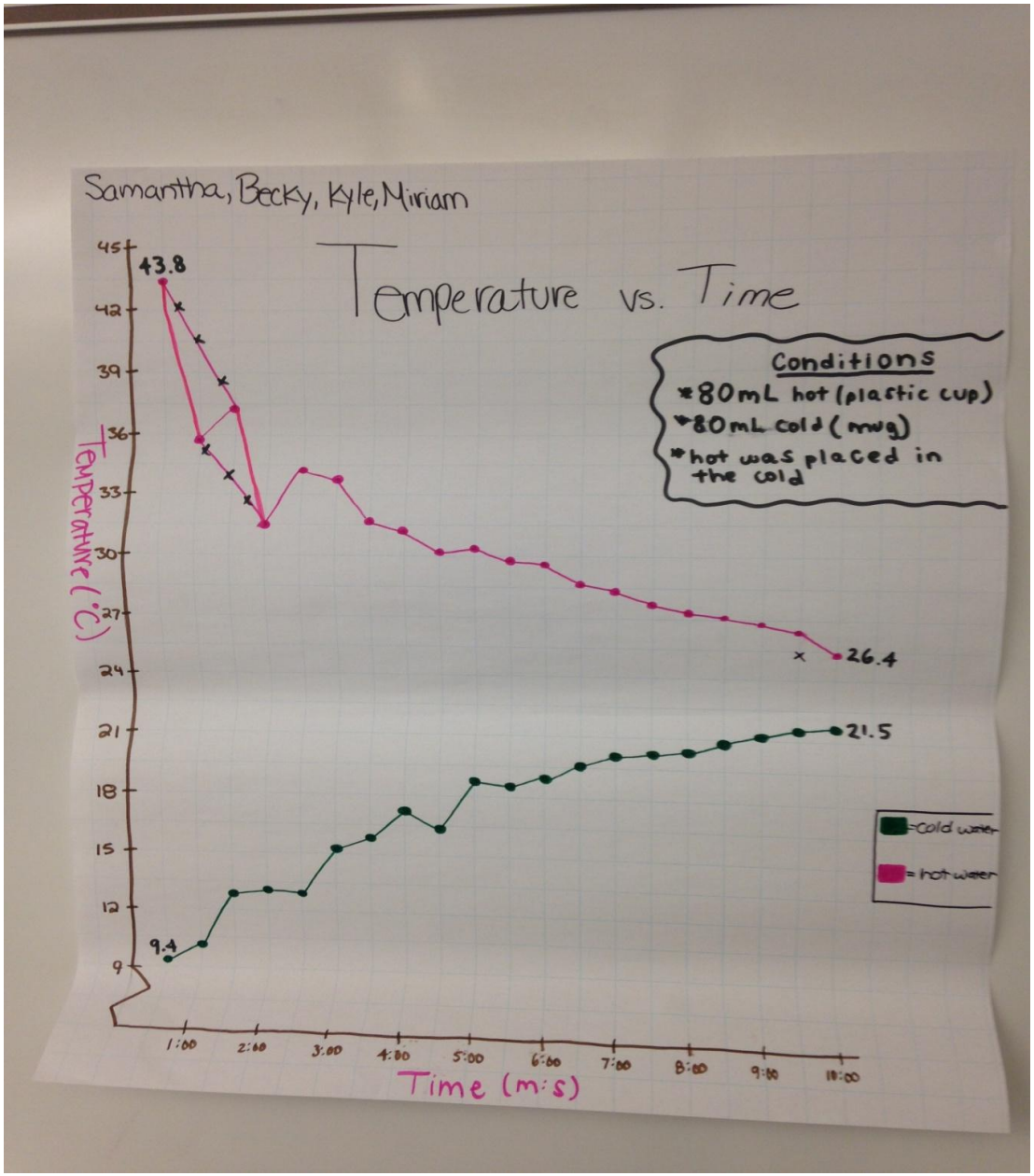

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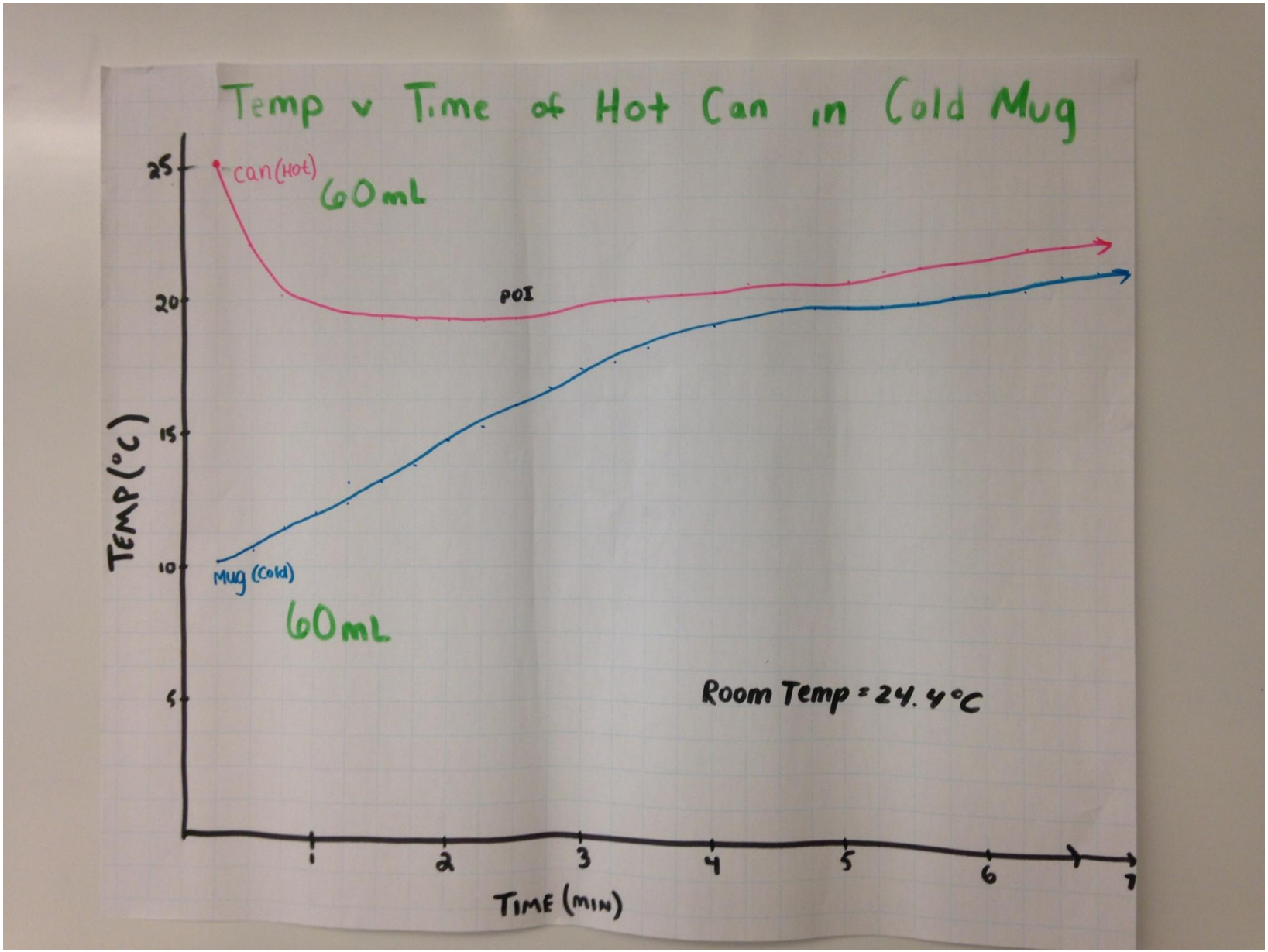

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