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On Cloud 9: Helping Students Relate the Concept of Differential Heating to Changes in Weather

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On Cloud 9

Graphic work by Joe Taylor

HELPING STUDENTS RELATE THE CONCEPT OF DIFFERENTIAL HEAT TO CHANGES IN WEATHER

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ABSTRACT: Understanding the basic features that drive the weather is important for understanding weather forecasting. In this activity students investigate differential heating and then connect that understanding to weather. Students are required to design a procedure, collect data, and make sense of that data. These investigative skills require students to be mentally engaged, and better model what scientists do while highlighting the inquisitive nature of science. *This activity promotes National Science Education Standards A, B, D, and G and Iowa Teaching Standards 1, 2, 3, and 6.*

Weather is an interesting topic to most students, and they are often curious how meteorologists make accurate predictions regarding the weather. The differential heating of the Earth's surface plays a fundamental role in weather. The inquiry approach described here demands that students think critically, work cooperatively with other students to gather data, effectively communicate, and develop a better understanding of several key topics relating to the nature of science (Saunders, 1992). Students are mentally engaged, enjoy the work, and are far more likely to develop a deep understanding of the targeted concepts.

This lesson should come after instruction that addresses ideas concerning how the Sun is involved in heating the ground, the ground's role in heating the overlying air, and the resulting movement of the warmed air. Prior to this activity the students should be asked to focus on the weather in certain land surface boundary areas (e.g. water next to land, sand near forest, etc.). This prior understanding will help the students towards the end of this activity when they are asked to connect what they have learned about differential heating to how it affects weather.

In teaching through inquiry, the teacher plays a crucial role in engaging students and helping them make desired connections. We provide several examples of questions we ask to help students connect ideas, to consider related factors, or to draw students' attention to certain ideas. Of course, no two classes proceed precisely the same, but by walking around the room and closely observing and listening to what students do and say, a teacher is in a position to interact with students in a way that individualizes instruction.

Day 1:

Understanding students' thinking is the foundation for effective teaching. To elicit students' prior experiences and ideas, we begin this activity by asking questions such as the following:

- “What are some experiences you have had where different surfaces in the same location have felt markedly colder or hotter?”
- “On a sunny day, what are some surfaces that feel hotter than others?”
- “On a sunny day, what are some surfaces that feel colder than others?”

Positive and expectant non-verbal behaviors (e.g. smiling, eye contact, inviting gestures, and wait time 1 and 2) encourage more student responses (Rowe, 1986; Olson & Clough, 2004). When generating this list, have a student write responses on the board, thus freeing the teacher to walk around the room monitoring and encouraging students. Placing student responses on the board helps to acknowledge students' ideas, encourage students to continue responding and stay engaged in classroom discussion (Lumsden, 1994).

Connecting differential heating of the Earth's surface to large-scale weather patterns gives the activity a more meaningful and important sense of purpose and direction. Thus we ask students to predict which large natural surfaces on the Earth they think would warm more quickly or slowly than others. This may necessitate providing examples of large tracts of land such as prairies, forests, clear-cut areas, deserts, etc. We follow this with, “If these surfaces warm to varying degrees, how might this relate to weather?” This question is asked to remind students that our investigation into differential heating is related to the issue of weather. Students' predictions about the differential warming of large natural surfaces on the Earth are a natural segue to inquiry. We initiate an investigation by asking students, “In the lab, how can you explore the effect of a heat source on the temperature of different natural surfaces?”

Initially have students work in pairs to develop a procedure. While the students are working the teacher should walk around the room observing and listening to students. Students generally know they should place different surfaces under the same conditions, but they may struggle in deciding how long they should heat the surfaces and how to measure the effect of the heat source on the surface (i.e. place a thermometer beneath the surface, on the surface, or measure the heat radiated off the surface). These are all important considerations, so hold a class discussion to address the pros and cons of suggested ideas. Acknowledge all students' ideas, and ask questions that help students decide which particular ideas make more sense. However, you might choose to permit students to test ideas that you know will be problematic. These experiences are important for better understanding the phenomena while at the same time experiencing how science does not march in a straightforward manner toward accepted ideas and procedures.

Ensure that students have considered what data they are going to collect, how they are going to record it, and the materials they need for their work. Pose questions such as:

- “What type of information are we looking for in this experiment?”
- “What materials will you need to simulate what happens in the nature?”
- “How will you set these materials up to accurately simulate the natural world?”
- “Given this type of procedure, what would be the best way to organize your data?”

These questions will help students remain focused and consider all they must do to successfully complete the task. Preparing for their work typically requires a full 40-50 minute class period. Students must know what they will do when they come to class the following day, and ensure that they have the necessary materials.

Day 2:

On day two of this activity, students should come in and begin working immediately. Their initial efforts will likely key students to the realization that some ideas do not work as well as others. Provide enough time for students to determine problem areas. At the appropriate time, have students report to the class on what they did. Work with the class to elicit the pros and cons of attempted procedures, and ask questions that help the class come to a more acceptable procedure. Ask questions that draw their attention to potential problems or solutions in their work. Once the class has come to consensus regarding a more adequate procedure, have them decide which groups will test which surfaces.

An important consideration here is deciding how many trials are needed and how students will decide their level of confidence in the results. These are decisions that scientists must make all the time, and having students do the same has value for understanding the investigation and how science works. Students should be encouraged to make connections and debate ideas with their fellow students. When the teacher solves the problem students realize they can simply wait for the teacher to give them direction rather than attempting to solve problems on their own. When consensus has been reached regarding how to proceed, send students back to work.

Because students are implementing a procedure that has been improved from their prior work, they more deeply understand what they are to do and why the procedure is appropriate. Because of this, students efficiently conduct their work and their efforts soon turn to recording their results and making sense of their data. As with other aspects of the inquiry, have students consider the pros and cons of various ways to convey their results (i.e. a data table, a graph, a chart, etc.). When most students have finished, bring the entire class together and compile the results on the board. Hold a class discussion regarding how the data might be presented, and the pros and cons of suggested ideas. Draw students' attention to how their work mirrors that of authentic science by asking questions such as:

- “How is what you have done thus far similar to what scientists do?”
- “How is what you have done not like authentic science?

These questions will help draw the students' attention to the collaborative work of scientists, how scientists must decide how to do their work, analyze their results, and how to communicate their work to colleagues or the public.

The students' original experiment designs most likely focused on daytime conditions. In order to get the students to analyze nighttime conditions, ask:

- “What part of the day do the procedures you conducted simulate?”
- “How would you simulate conditions at other times of the day?”

Then students should be given time to adjust their set up to mimic different times of the day and night. While the students are revamping their procedures the teacher can walk around the room ensuring students are staying on task and guiding students through questioning. If the students are stuck on how to account for different times of the day and night, ask questions such as:

- “What is different about the sun's position at different times of the day and night?
- “How can we simulate this in the experiment design?”

As students make changes in their set up, ask questions such as:

- “What is your rationale for adjusting that part of the lab?”
- “What part of the day (or night) does this set up represent?”

So that students think about these sorts of issues, we require students to speak to us before implementing their procedures. This also ensures we have the opportunity to ask questions that help students resolve problems before proceeding. How much students complete this second day depends on a number of factors. We keep an eye on the clock to ensure clean-up begins a few minutes before the end of class and remind students to immediately begin working when they arrive at class the following day.

Day 3:
The students should arrive ready to complete their work. We walk around observing what students do, listening to what they say, and interacting when appropriate. Questions we ask on this day address how the data they are collecting compares to previous trials and how students account for the similarities and differences.

When the students are nearing the completion of their work, we tell them to place their data on the board. We stress the need for students to work together by saying “You are responsible for ensuring all the data is placed on the board in an organized manner”. When all the data has been placed on the board, clean up is completed, and students are back in their seats, we hold a class discussion where questions such as the following are asked:

- “Which materials absorb or release heat the fastest?
- “What trends, if any, do you infer?”
- “What do you think is happening to the air above each material during day and night conditions?”
- “How might this differential heating and cooling be related to weather?”

Beyond the affect on air temperature, the connection to weather is rarely understood by students. Ask questions that spur thinking about how this heating and cooling process drives the weather. Ask questions such as:

- “What happens to the heat captured by the ground material?” This question is asked to ensure students understand that the heat is released and warms the air.
- “What happens to air as it is warmed?”
- “When the air rises, what is left in its place?”

These questions are designed to link what students have learned about differential heating of the

Earth's surface to previous lessons regarding air temperature, pressure, and density. Thus, they serve as both a means to assess students' understanding of previously taught content, and to help students make new connections.

Appropriately scaffolded questions help students come to understand that warm air rises, and dense cooler air rushes in its place. Referring to their laboratory work, students know that water surfaces are far more resistant to wide swings in temperature than land surfaces. Ask,

- "Where large bodies of water exist next to land, what patterns of air movement would you expect during the day when the Earth's surface is warming?"
- "Where large bodies of water exist next to land, what patterns of air movement would you expect during the evening when the Earth's surface is cooling?"

We connect this to the weather watching activity we had students perform prior to the differential heating activity by asking:

- "What did you notice about the weather in places close to the water compared to places surrounded by land?"
- "How does this compare with the data you collected in the activity?"
- "What happens to the pressure above the surface in these different conditions?"

Students are now in a better position to move on to other lessons such as pressure systems, wind, air mass movements, and other connections to weather.

In Summary

The questions we have provided are examples of the kinds of interaction we strive to create. Use questioning to respond to incorrect student ideas and to guide students toward more accepted scientific ideas. Maintaining an environment of inquiry is important throughout the activity. Begin with the activation of students' prior knowledge (recalling how things feel on a sunny day), use this to bridge to ideas regarding the heating of different surfaces, and then scaffold to air movement and weather. This approach requires a higher level of cognitive engagement than simply providing students with the necessary information. The events students have experienced and the conceptual links they have made during the ensuing discussions help them better understand and wrestle with future readings we assign. The time devoted to inquiry pays off handsomely in students' deeper understanding of the targeted science content, greater interest in science, and a better understanding of how authentic science takes place.

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