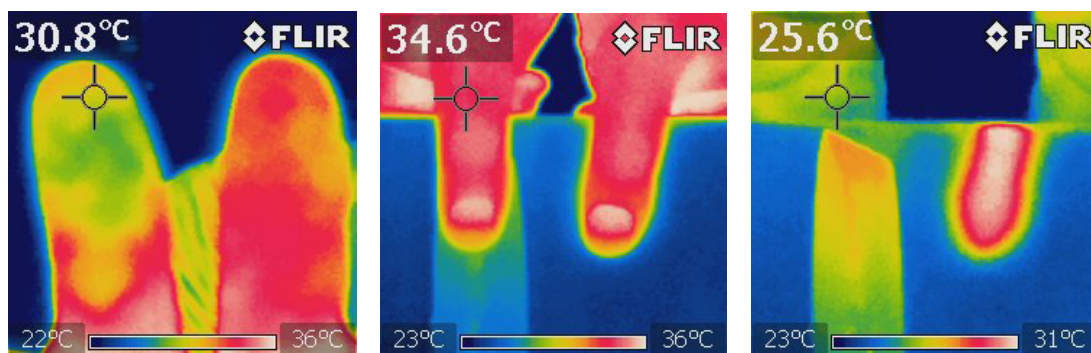


Experiment:

Metal strip and wooden spoon

Central concepts:

- Thermal properties of materials and objects
- Heat conduction
- Heat insulation
- The sense of touch is not a reliable thermometer



Purpose of the experiment

Metal feels colder at room temperature than many other materials, such as wood or plastic. With this experiment, students are given the opportunity to explain this phenomenon as a consequence of the differing heat conductivity of involved materials. Whereas wood and plastic are thermal insulators, metals are good thermal conductors. Students are also given the chance to relate their sense of touch to the concepts of heat and temperature, respectively. The exercise targets the common – but inaccurate – conception among students that their sense of touch is a reliable thermometer, and encourages them to conceive of their hands as warm objects that conduct heat to objects of lower temperature with which they are in contact.

Expected outcome

When students touch the wooden and metal objects, they are likely to experience that the wood feels “normal”, but that the metal feels cold, and to predict that the metal has considerably colder temperature than the wood. When they measure the temperatures of the objects, they typically experience a cognitive conflict when they see that the wood and metal are of roughly the same temperature, that of the surrounding. In turn, when asked to hold the objects for about 2 minutes, they typically expect accurately that the metal will warm up quicker than the wood. If encouraged to focus on the part of the metal closest to the hand, they can typically explain the increased temperature as due to heat conduction from the hand. When the hands are removed from the objects, the metal object has more uniform temperature, while the piece of wood has been heated only locally at the point of contact with the hands. However, many students, also at the secondary level, and non-scientist adults, retain the idea that their sense of touch is a reliable thermometer, and may have difficulties interpreting the results of the laboratory exercise. Some participants have been found to question the measurement equipment, both the in case of traditional thermometers and IR cameras.

Relevant age groups

The exercise may be used as part of the introduction of thermal properties of different materials, whether they are heat conductors or heat insulators. For instance, in the Swedish year 4-6 physics curriculum, “Energy flows between objects with different temperatures. How the flow of energy can be affected by such means as clothes, thermos and house insulation”, is listed as a core content. At higher age levels, the exercise may be used to introduce how the physical quantities heat conductivity and heat capacity relate to one another, and students may be encouraged to provide microscopic explanations of the mechanism of heat conduction due to molecular interactions.

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Added value of IR cameras

In the first part of the task, where students predict the initial temperature of the objects, the main value of the IR camera in relation to traditional thermometer measurements is the real-time visual input of the equivalent temperatures of the objects. The real value of the IR cameras is given in the second part, however, where the students are given the opportunity to see a heat flow from their hands to the metal object with their own eyes. Previously, without using an IR camera, they have had to imagine such a heat flow before their minds' eye.

Tips and tricks

Our experience is that the exercise is quite challenging for students at all ages. In particular at younger ages, we would recommend combining the predict-observe-explain approach with explicit teaching of a heat-flow model, according to which heat flows from objects of higher temperature to objects of lower temperature.

The exercise may be used in conjunction with other exercises targeting the idea that the sense of touch is a good thermometer. For instance, the students may be encouraged to place one hand in ice cold water and the other in hot water for some seconds, and then move both to tepid water. The tepid water will be perceived very differently by the two hands, which means that a substance of a certain temperature may feel very differently by the sense of touch.

If the metal object has a shiny surface, it may have lower emissivity than the wooden object and reflect IR radiation from surrounding lamps and the bodies of the participants, which influences the IR camera readings. This may be framed as measurement inaccuracy with younger students, but provides an opportunity to discuss the properties of IR radiation with older students.

In our experience, due to the material and thickness, heat conduction from participants' hands to some metal objects does not result in a sufficient temperature increase to be seen with the IR cameras. We recommend using thin metal objects, such as metal strips, and suggest considering fixed temperature scales on the IR camera. Part of the exercise is to connect the embodied experience of the sense of touch with the IR camera readings, but a way to make heat conduction more visible is to put the end of the metal object in a flame or in a cup of hot water.