“My fingers are cold”, modelling thermal phenomena in the hand

Nada Razpet
(nada.razpet@guest.arnes.si), Faculty of Education Koper, Faculty of Education Ljubljana, Slovenia

Introduction

Teachings of natural sciences have changed recently in our primary schools. New school subject was introduced which connects physical, chemical, and biological topics and is called Science. A nice example of connecting theme is conservation of body temperature. We did not want to present this subject only from theoretical point of view therefore we prepared a set of practical models. The simple hand fingers and palm model was evolved and improved during the project as we investigated how different external circumstances affect the temperature. At the end we measured temperature of real fingers and palm and compared results with the model.

We were additionally motivated to carry out our planned activities by the news from our alpinists who were climbing mountains in Himalaya at that time. Frostbites due to extremely low temperatures are frequent events on such expeditions. Usually fingers and toes suffer the most, but noses and ears follow immediately

Activities

We started with measurements on a simple model. The volume of a human hand was measured first. We found out that the volume of a typical hand was about 300 ml. We took a latex glove; we filled it with 300 ml of water at 37°C and put it on a table. Another two latex gloves were filled with the same amount of water at the same temperature, but dressed additionally in wool gloves, one the four fingers kept together in the same pocket of the glove and the other with one pocket for each finger. After 20 minutes, we touched the gloves and felt the difference. The naked latex glove was cooled down the most, the woollen glove with fingers was warmer and the woollen glove without separate finger pockets was the warmest. To investigate which external circumstances influence the measurements, we changed the surface on which the gloves were lying. It was obvious that the influence of the surface was strong. Such simple models are suitable for younger pupils, especially if the temperature of the water in a glove is much different than the temperature of surrounding air (if experiments are performed outside during winter).

Temperature was measured with IR thermometer. We found out that measurements were not as precise as we hoped for. The thermometer grasps radiation from a wide angle and not only from tiny fingers therefore were temperatures of fingers not determined very accurately. Palm temperature could be measured more precisely because of its larger surface.

To exclude the influence of the surface the gloves were hanged from a rope. Immediately we observed that convection in water becomes important. Warm water went up and cold water went down into fingers. Temperature of the fingers which were positioned below the palm was therefore additionally lower than temperature of the palm due to the water convection.

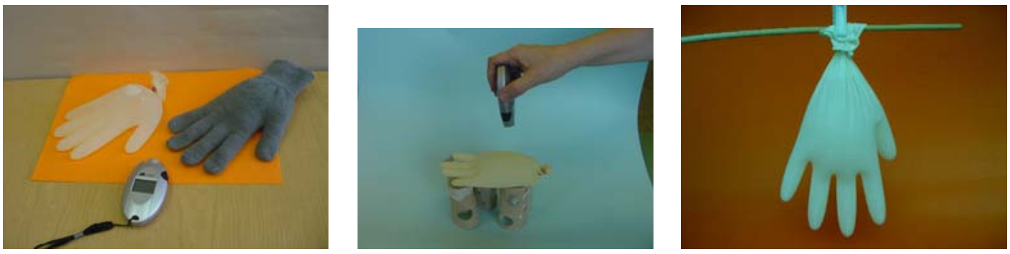

Figure1. Measuring the temperature.

Next, the gloves were put onto the paper cylinders which were perforated to enable the air convection around the glove. For measuring temperature the IR thermometer was used therefore results were a bit imprecise but nevertheless they supply an approximate picture how the temperature of the fingers and the palm changes with time.

Time (min)	0	2	4	10	15	20
model palm (T[°C])	40	39	37	33	30	28
model fingers (T[°C])	40	35	30	29	25	23

Table1. Temperature of fingers and palm on the model changes with time.

Differences in temperatures are large enough to conclude that for our model of the human hand the temperature of the fingers is lower then the temperature of the palm (the temperature of air was 3°C).

Measurements of the temperature of the human hand

Temperature of the fingers and the palm was measured outside when the air temperature was 3°C with the IR thermometer.

Time (min)	0	10	15	20
human palm T[°C]	36	24	22	20
human fingers T[°C]	34	21	16	10

Table2. Temperature of fingers and palm (human) changes with time.

After standing twenty minutes in the cold outside the temperature of my palm was 22°C and the temperature of my fingers was 10°C. Measurements were approximate since it is important how fingers were positioned during these 20 minutes. If they are together the temperature of the middle finger is not the same as temperature of the little finger or the thumb. If fingers are kept apart the measurements are influenced by the surrounding (IR thermometer grasps radiation from a wide angle). However measured temperatures show that fingers get cold sooner then the palm.

Afterwards I warmed my hands above the heater and measured how the temperature of my fingers and palm was changing again. As before I found out that the temperature of the fingers changes faster then the temperature of the palm.

We have evolved our project further. We have asked students of Physics and Technology at our department at Faculty if they would accomplish more precise measurements of finger and palm temperature with NTC thermistor connected to a computer, which automatically records measurement data. To protect a vulnerable sensor we have measured temperature between the latex gloves, which were put onto students' hands, and their skin. Students put their hands with latex gloves and temperature sensors into the mixture of snow and water (which temperature was close to 0°C) and keep them there until they could endure (but not too long, to avoid frostbites). They acquitted themselves well. Here I present one set of recorded measurements. Time interval between subsequent data is 4 seconds.

Time (sec)	0	4	8	12	16	20	24	28	32	36	40
human palm T[°C]	35.2	33	31	29.5	28.4	27.6	26.9	26.3	25.9	25.5	25.2
human fingers T[°C]	30.2	25.9	22.3	20.1	18.7	17.9	17.4	17.0	16.6	16.3	16.1

Table2. Measurements of fingers and palm (human) after submerging in cold water with NTC thermistor.

After 40 seconds fingers cooled down for approximately 14°C and palms for 10°C.

We were also interested how temperature of fingers and palm changes when the hand is sunk into the hot water with temperature around 45°C. Here are results.

human palm T[°C]	32.8	34.1	35.6	36.4	36.9	37.2	37.4	37.7	37.9	38.1	38.3
human fingers T[°C]	22.9	26.2	28.5	29.7	30.6	31.2	31.6	32.0	32.2	32.5	32.7

Table3.: Measurements of fingers and palm (human) after submerging in cold water with NTC thermistor in 4 seconds intervals.

Computer recorded temperature in time intervals of 0.20 seconds. It was interesting to find out that differences emerged out between individuals. Initial temperatures of fingers and palms of students A, B, … H are presented in the following table, to compare.

T[°C]	A	B	C	D	E	F	G	H
human palm T[°C]	32.8	35.2	35.2	32.7	29	25	25	29.3
Human fingers T[°C]	22.9	30.2	30.2	28	23	24	21	25.5

Table4.: Initial temperatures of fingers of student's hands.

Other observations and explanations, which can be performed and given during the experiment:

It should be explained to pupils how the organism spontaneously responses to a temperature change. Of course organism response can not be observed with models. What do we could observe and talk about?

When it is cold:

1. Hairs stay on end due to contraction of muscles which lie in the skin. People experience these as creeps. Some animals have hairy fur coat which protects them against coldness with an isolative layer of air which is caught in fur coat. It is especially interesting to discuss about animals that live in Polar Regions

(penguins, polar bears). People do not have such an excellent thermo protection which is why we need clothes.

2. Thin blood vessels in the upper skin layer contract, therefore less blood reaches the skin the amount of heat lost from the core is reduced. This phenomenon can be seen clearly at noses, ears, fingers, which jut out from the bulk human body. These parts of the body have large surfaces with respect to their volumes and consequently they cool faster.
3. Processes of metabolism intensify. Due to the coldness the amounts of hormone thyroid in the blood increase. The thyroid hormone reaches all the cells of the body and increases their metabolic activity which increases heat production. When it is cold around us, we shiver. Shivering with cold is spontaneous and stimulates metabolism in muscles.
4. If a person is exposed to low temperatures for too long, brains suffer first, then metabolism is reduced and consequently less heat is produced to warm the body. When the internal temperatures falls below 25°C, death is imminent.

When it is hot:

1. Hairs lay down by the skin.
2. Thin blood vessels in the surface layers of the skin broaden and flow of the blood through the skin increases.
3. Metabolism processes reduce and the heat production is smaller.
4. The body perspiration gets more intense. Cooling down with perspiration is the only possible way of cooling when the temperature in surrounding is higher then the body temperature.

Conclusions:

We used several methods for measuring temperature. We have shown how to conduct an experiment when starting with a simple model and how to evolve it. We used measuring equipment that is widely available (IR thermometer) and connected to computer. We have shown that fingers cool faster then the palm (both on a hand model and on a real human hand) and connected this finding with examples of biological response to cold temperatures.

For more precise measurements the temperature of all hands should be the same. In this case, we can also measure the difference between cooling of small and big hands and the difference between hands of children and adults of both genders. A vulnerable NTC thermistor measured temperature within the glove as it can't be used in water. In the meantime, even better thermometers became available. We are planning a new experiment where different glove sizes will be compared in order to understand the effect of volume–surface ratio of the hand.

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