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THIRD INTERNATIONAL SEMINAR ON MISCONCEPTIONS AND EDUCATIONAL STRATEGIES IN SCIENCE AND MATHEMATICS

MISCONCEPTIONS ON HEAT AND TEMPERATURE

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In recent years misconceptions have become a popular subject of study within physics education research. Research has shown that these misconceptions are not usually simple mistakes, but rather are the result of systems of common sense theories that are so stable and coherent internally that conventional instruction has little effect on them. So, the goal, from an education viewpoint should be to find strategies to make instruction more efficient and to determine at what age or grade children are more open to learning what are traditionally considered difficult concepts with less interference from common sense theories.

The work I am reporting is part of a several approaches I have designed to teach what are usually considered difficult topic in elementary school. The methods used depend on the subject to be taught and vary greatly, from simple story telling to learning through discovery. All sessions include a problem based approach centered on real life situations which are familiar to the children.

I used ethnographic methodology, recording all events during a class or workshop via a trained observer in order to evaluate the tactics used. An analysis of these recordings is done later. Since only ethnographic observation was used, the conclusions are mainly qualitative, which is to say, that the purpose was not to calculate percentage-wise the number of students affected by common sense theories, but rather to identify the types of common sense schemes present in the students. The information gathered was used to give direct feedback to instructors.

When dealing with heat and temperature while working with elementary school children, the most efficient method appeared to be the use of experimental workshops with calorimetric experiments. The work reported was done with elementary school children (rural and urban) between the ages of 7 an 11, as well as with high school students. In evaluating the latter group paper and pencil testing was used as well as ethnographic observation.

Among both groups the main sources of misconceptions were found to be real life phenomena, mostly acquired through the sense of touch. Students tended to apply language used in physics, but with meaning different from those of the specific physics concepts they should be associated with. One of the most basic references in the sense of touch conditioned by the temperature of the human body.

The misconceptions held by children before the workshop were identified through problem based questions of real life situations, as well as through interviews made before each experiment. With high school students a pencil and paper test, based on the common sense theories found in the children, was used.

The workshop consisted of simple experiments using the thermometer: measurement of temperature versus sense of touch (room temperature, water temperature, body temperature), temperature of water being warmed or cooled, conduction of heat through a copper stick versus a wooden one, measurement of the time take by different liquids, originally at the same temperature, to cool down to a specified temperature.

The most important findings related to children's schemes were the following:

* Although children say that heat and temperature are two different things they use the words interchangeably.

* Children use analogies to define heat and temperature. They identify heat with fire, the sun or "what is used to heat things". Temperature was identified with the wind,

air, cold and fever.

* The belief that room temperature is zero.

* The belief that the temperature of the human body is equal to room temperature.

* The belief that body temperature is inverse to room temperature. In the latter increases the former decreases.

* The belief that objects have their own temperature.

* More rural than urban children recognized that different liquids require different lengths of time to cool off. They also knew that in the kitchen it is better to use wooden spoons than metal ones.

After the workshop the children's conceptions had suffered important changes:

* Children recognized that thermometers give us information different from that received through the sense of touch.

* Children explained heating and cooling in terms of heat interchange, in a caloric model fashion.

* Children explained that if some materials warm more slowly than others, they also cool off more slowly.

* When children were asked about thermal equilibrium via though experiment (i.e. think of a piece of hot metal that is introduced in cold water), the majority predicted thermal equilibrium.

From the problem based session and interviews performed before each experiment with high school students, the following misconceptions appeared to be the most prevalent:

* Objects have their own temperature.

* Body temperature was considered higher than room temperature by the majority of student, but some students considered it constant, equal, proportional or inverse to room temperature.

The interviews also provided the following information:

* There was an excessive use of "physics words" in explanations. The students seemed to be more interested in adjusting the experiment to the theories they held, than in looking for a better scientific model.

* Perception of physics as an "ideal subject" and the belief that "it only applies to idealized situations, not to reality".

* The energy concept did not appear in the students' explanations. When they were asked about it, the majority related it to mechanics.

* The main argument in favor of their explanations seemed to be the "physics concepts" rather than the real phenomena.

After the workshop the changes we observed in the high school students were not as marked as in children. In fact, most of the initial conceptions remained:

* When those students who seemed to have changed their schemes were given a problem with different condition to those treated during the workshop, they frequently reverted to their previous schemes.

* A large number of students explained that thermal equilibrium was held when each object had reached its own temperature, maintaining the earlier conception that each object has its own temperature.

* The students who predicted thermal equilibrium thought of heat as a "caloric-like" substance.

High school students' misconceptions were found to be harder to be explored and more deeply rooted than those of the children studied. Also, high school students' conceptions tended to be far from simple, reflecting their vision of physics, or at least of the way physics is learned, or taught. It is important to note that while children don't really have an "physics" idea about temperature and don't seem to be in need of replacement of common sense theories, high school students do have strongly rooted misconceptions.

In order to overcome these misconceptions, it was necessary to use other activities beside the experimental workshops. These activities were planned to emphasize the inconsistencies of the models held as well as the phenomenological comprehension of the theories to be learned and the application of the theory on a wide range of phenomena. Explicit instruction on the subject was necessary and even after instruction some students still tended to reason using the earlier misconceptions. The activities took more time than the experimental workshop.

On the other hand, with children, a short discussion of the experiments is sufficient for them to change their previously held models. After the explanation, they are even capable of applying the theory to other phenomena. For instance, the kind of questions we deal with after the workshop are:

"If we put a hot marble in cold water, what will happen to the temperature of the marble and of the water? After a long time, which one will be warmer?"

"Why are there some places like the desert where it is really hot during the day and extremely cold at night?"

The majority of the children usually predict thermal equilibrium in the first question, and explain the second one in terms of the heat kept in the environment during the day, resembling the concept of heat capacity. Explanation during explicit instruction used after students' have had time to ponder the questions is very easy since it is a matter of giving the proper name to concepts that the children already perceive as important, concepts such as thermal equilibrium, conductivity and specific heat.

The most important conclusion of this research is the importance of providing children with phenomenological references in experimental workshops on heat and temperature during the first years of elementary education. Heat and temperature are strongly related with everyday life, which enforces misconception seem to be harder to change as time passes. At the same time they are one of the physics topics that can be most easily related with other phenomena that make them relevant for children.

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