Students' Alternative Conceptions in Pressure, Heat and Temperature

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Objective

To study the undergraduate physics students' misconceptions about some selected basic concepts in thermodynamics.

Significance of the study

At the core of physics education research is the desire to improve instructional strategies for the benefit of student learning. In the physics community, there has been much research undertaken to this end yielding revealing data about what and how students learn. The identification of various misconceptions has led to new ideas for teaching physics both at the secondary and undergraduate levels.

Heat and thermodynamics is a conceptually rich area of undergraduate physics. From the point of view of misconceptions it seems not to have been explored much. Especially in the Indian context so far there has not been much work done in this area. This has prompted us to undertake the present study.

Theoretical Framework

One aspect of misconceptions is that they are part of a student's line of reasoning (Maier, 2004). A misconception is more than having a fact incorrectly memorized. It originates from an inaccurate/inadequate mental structure that underlies one's thinking of a group of related concepts.

Physics is a very conceptual subject. Misconceptions in physics get developed at very basic levels. It is well understood in the physics community that misconceptions must be addressed if they are to be overcome. If not confronted at right time, they keep floating in the students' conceptual framework even to their undergraduate period.

Ironically, at the root of the development of a misconception lies its remedy. In Piaget's model of intelligence, what is required for sound understanding of a concept is accommodation following a state of disequilibrium. If the student experiences are skillfully guided at this stage, the misconceptions which may develop by way of unchecked accommodation may be avoided or disentangled. In other words, according to this model the way to prevent or resolve misconceptions is to have the learner confront the misconceptions directly with an experience that causes disequilibrium followed by sound accommodation (Maier, 2004). It is thus clear that study of misconceptions could be of great help in instruction, particularly in physics instruction.

The present study is on misconceptions that arise in introductory thermodynamics. We have focused our attention on three basic concepts 1) Heat, 2) Temperature and 3) Pressure. A large number of experiences in daily life is related to these concepts and as a result students develop some kind of naive models about these concepts right from their early school days. When such concepts are taught to the students in a way that does not provoke them to confront paradoxes arising from their alternate models conflicting with the 'standard scientific model', they develop misconceptions. The process of development of misconceptions may also be aided by use of words that mean one thing in everyday life and another in a scientific context (e.g. pressure) and by the learner's inability to overcome non-scientific beliefs.

Previous studies have revealed that the terms 'heat', 'temperature' are frequently not differentiated by students (Errickson, 1985). They do not consider surroundings to be important for an object's thermal history (Tiberghien, 1985). The concept of thermal equilibrium is not well understood by them (Strauss and Stavy, 1983) (Arnold, M. Millar R. 1996). Our study confirms these observations. Further we find that students' ideas of pressure are limited to 'force per unit area' and their model of pressure is essentially that of 'weight of a vertical column per unit area of cross section'

Table 1

Items	Did not Attempt	Correct Response	Incorrect/ Inadequate Response
Heat – Basic Concept	10%	20%	70%
Temperature – Concept	40%	0%	60%
Internal Energy and Total Energy	20%	20%	60%
Thermal Equilibrium – Relation to object material	10%	0%	90%
Thermal Equilibrium – Relation to object size	10%	20%	70%
Latent Heat – Constancy of temperature	0%	60%	40%
Temperature – as an Intensive Variable	30%	40%	30%
Pressure – Basic Concept	50%	10%	40%
Pressure – Variation with direction	10%	50%	40%
Pressure – Variation with location	30%	0%	70%
Pressure at a point inside a container	20%	40%	40%

Research Design

We conducted a preliminary study involving discussions with some undergraduate students. This study gave us clues to the kind of difficulties that students have in the topics of our study. On the basis of this study as well as through discussions with some college teachers, we framed a free response test consisting of open ended essay type or short answer questions. This free response test was administered to a sample of 30 undergraduate students in a Mumbai college. The responses to this test were analyzed. In order to probe students' ideas further, interviews were conducted with a few students. This exercise of free response tests and interviews brought out problem areas and helped us identify misconceptions in a broad sense. With this background, we formulated forced option tests to pin down the misconceptions further. The forced option tests are being given to a larger sample of undergraduate students from colleges in Mumbai. For further confirmation/probing detailed interviews will be conducted with a few selected students.

Findings

Table 1 summarizes how students responded to various items in the free response test. The column 'Items' gives the main concept to be tested through the item. The other columns give the percentage of students who did not attempt the item, whose response was 'correct' and whose response was 'incorrect /inadequate'. The prominent findings are given following the table. We intend to present a detailed analysis in the poster format at the conference.

Many students when asked what heat is, can not go beyond a statement "Heat is a form of energy". Some of them relate it to temperature saying that "Heat increases temperature". Some talk about heat as the energy content of the system. They seem to equate heat with internal energy. Neither any student mentions that heat is a form of energy in transit nor anybody shows awareness that heat may lead to external work.

In case of temperature, some students seem to equate it to its unit "degree centigrade". Some say that it measures the 'heat content' of the body. Some use a kind of 'inverted reasoning' to make statements such as "temperature causes change in heat" or "temperature is the unit which determines particular states of a body".

When asked about internal energy, many students seemed to equate internal energy of a system with the total energy of the system.

Thermal equilibrium is a problem area for the students. They were asked about the temperature attained by a body kept in a hot enclosure for a sufficiently long time. They seemed to say that the temperature attained depends on the material of the body or on its size. The materials stated in the relevant item were copper and wood. Copper being a good conductor of heat, was rated as a candidate for a higher temperature than wood which is a non-conductor. Some of the interesting statements were

"In copper, heat affects inner particles, whereas wood absorbs heat only at the surface".

"Wood will resist the change in temperature".

In case of size dependence some students argued that a larger body will have larger temperature (thinking that larger surface area will absorb more heat and hence lead to a greater temperature) whereas some other students said that a smaller body will have larger temperature (thinking that a given amount of heat will result in greater temperature for a smaller volume. They seem to intuitively think of heat as a liquid and the temperature as level of the liquid.)

The concept of latent heat seemed to have no great problem with students. Most of them answered that the boiling point of water will remain constant even after the gas stove is turned on to a higher flame. But there were some exceptions going for 'increased temperature' argument.

The intensive nature of temperature is not understood by the students. Some of them answered that if a container is portioned in two unequal compartments their temperature will be different.

Most students' ideas of pressure did not go beyond 'force per unit area'. They seemed to have a 'weight of column' model of pressure wherein the pressure changes with the height of the column. While applying the model they do not show any sense of the relative magnitude of the density of air and that of liquid, say water. Due to this 'weight of column' model another misconception that students are led to was that a fluid exerts no pressure on the vertical walls of the container.

References

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