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Prospective teachers' conceptual understanding of phenomena related to thermal physics and its evaluation

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Abstract

In this work we present a questionnaire that has been given to prospective teachers in the Department of Primary Education of the University of the Aegean and represents an attempt to examine prospective teachers' views on concepts related to thermal phenomena as well as to improve students' understanding of these concepts. The students' answers have been classified according to the orientation of studies selected in order to be admitted to the Pedagogic Department and the results are presented here. The results reveal that perspective teachers share a number of misconceptions about thermal phenomena while the fewest misconceptions are present among the ones come from the scientific orientation.

Key words: evaluation, physics, heat, prospective teachers's conceptions.

INTRODUCTION

In recent years there is a growing research activity regarding the factors that affect the teaching of physics in prospective teachers for primary school. Some factors results from the education research, the incorporation of information and communication technologies in the education process, the physics content knowledge etc. (Thacker, 2003). This implies a focus on conceptual understanding and the cognitive skills required to understand and apply physics concepts, interactive methods for teaching and learning, change in science curricula and the incorporation of teaching methodologies into the Physical Sciences curriculum of the pedagogical departments (Kokkotas, *et al*., 1998).

Consequently, teaching and learning in Sciences must not be restricted only in accumulation of knowledge on concepts, but it must to extend on the developing of scientific skills that are related to the application of knowledge, development of scientific thinking and skills on problem solving. (Hatzikraniotis *et al*., 1999; Woolnough, 1989).

On the other hand, research has shown that teachers with who have well developed subject matter cognitive structures are more efficient at presenting subject matter to students (Nott & Wellington, 1996; Gess-Newsome & Lederman, 1995, Valanides (2000), Summers (1992) & Valanides (2000)), the majority of primary student teachers hold views of science concepts that are not compatible with the scientific ones and obviously this influence children's understanding of science related concepts (Nott & Wellington, 1996; Gess-Newsome & Lederman, 1995; Johnson, 1998) and teachers seem to hold "inadequate conceptions" of science (Hodson, 1993, Papageorgioy & Sakka, 2000) or have ideas which are not scientifically accepted.

Valanides (2000) reports also that primary student teachers have limited understanding of the particulate nature of matter and the relation of observable macroscopic changes (i.e., change of phase) and it will affect their classroom behavior and teaching methods.

In this work we present the design and the implementation of a questionnaire constructed for the specific purposes of the present study and presented to prospective teachers of the Pedagogical Department of the Aegean University.

From the study it is evident that students misunderstand fundamental concepts related to thermal phenomena, some they are not familiar with the terminology of concepts related to thermal physics and some concepts are perceived in a limited way.

The study will extend next semester with the creation of a series of worksheets to accompany the questionnaire.

DESIGN OF THE STUDY

The purpose of the study was to investigate prospective primary school teachers' conceptual difficulties in understanding basic concepts and phenomena related to heat after they had received a course of instruction on heat energy. In the study we tried to focus on misconceptions about the difference of heat with temperature, the transfer of heat and the states of matter but we have remained on an elementary level. The study involved 33 of the Pedagogical Department of the University of the Aegean that come from the Scientific orientation (7), the Technological orientation (10) and the Theoretical orientation (16), and attend the subject "Children's Views on the Concepts of Physical Sciences". The students are in their first or second year of their studies and they are prospective teachers for primary school. The course is scheduled for three hours per week and lasts for twelve or thirteen weeks.

The course consists of mechanics, heat and optics. Students were informed that the information from the questionnaire was to be used for the design of the course and it is anonymous.

Prospective teachers have had experiences about teaching and learning in science concepts related to heat and thermal phenomena as students in secondary education.

All the prospective teachers had attended lessons on heat in lower secondary school while those that had selected the Scientific and Technological orientations had been taught a significant part of the heat engines and kinetic theory of gases in the second year of the upper secondary school.

The study was conducted after they had received both classroom and laboratory instruction on thermal physics for about two months (2 hours per week for classroom lecture and 1 hours per week for laboratory instruction).

The completion of the questionnaire lasted 60 minutes. Data from the questionnaire were classified according to the orientation they had selected in order to be admitted in the Pedagogic department. In the sample, 5 of the 33 students were men and 28 were women.

FINDINGS

Data from the questionnaires are presented in Tables 1-8.

Question 1. Define the term "Heat"

Prospective Teachers' responses

Scientific orientation	Correct N=4	Incorrect N=2	Irrelevant N=1
Technological orientation	Correct N=3	Incorrect N=6	Irrelevant N=1
Theoretical orientation	Correct N=1	Incorrect N=5	Irrelevant N=10

Typical Responses by the prospective teachers.
1. A kind of energy transferred from one body to another.
2. The warmth we feel in our body, or the warmth we feel when we touch things in the space (inner and outer space).
3. A kind of energy. It is a thermal energy that can be transferred from one body to another through the oscillation of molecules.

Question 2. Define the term "Temperature".

Prospective Teachers' responses

Scientific orientation	Correct N=4	Incorrect N=2	Irrelevant N=1
Technological orientation	Correct N=3	Incorrect N=6	Irrelevant N=1
Theoretical orientation	Correct N=2	Incorrect N=5	Irrelevant N=9

Typical Responses by the prospective teachers.
1. A property which shows how cold or warm is a body. It is measured in Celsius or Kelvin.
2. The measure of the average kinetic energy of molecules.

Question 3. Suppose that you have a thermometer that can measure any temperature in the Celsius grade. Under this assumption the smallest temperature that you can measure through the thermometer is …..ºC, while the maximum temperature is ….. ºC.

Prospective Teachers' responses

Scientific orientation	Correct N=2	Incorrect N=3	Irrelevant N=2
Technological orientation	Correct N=1	Incorrect N=5	Irrelevant N=4
Theoretical orientation	Correct N=1	Incorrect N=7	Irrelevant N=8

Question 4. (Hypothetical Experiment)

a. I make a snowball and put inside it a thermometer which indicates 0ºC. I hold the snowball with my hands as long as I can stand it. The indication on the thermometer will: a. rise over 0ºC b. be 0ºC again c. start to rise, but afterwards it will show again 0ºC d. I have no opinion.

Justify your answer.

Prospective Teachers' definition

Scientific orientation	Correct N=2	Incorrect N=4	Irrelevant N=1
Technological orientation	Correct N=2	Incorrect N=5	Irrelevant N=3
Theoretical orientation	Correct N=1	Incorrect N=5	Irrelevant N=10

Typical Responses by the prospective teachers.
1. The temperature of our body is over 0ºC. For this reason, heat will be transferred through our hands to the snowball, and after a while the ball will start to melt.
2. The thermometer will show 0ºC, though heat is transferred from our hands to the ball and conversely.

Question 5. I wrap an aluminium foil around a big snowball, and force inside a thermometer which indicates 0ºC. I keep the snowball with naked hands as long as I can. After a while the indication on the thermometer will be:

a. over 0ºC b. be 0ºC again c. below 0ºC d. I have no opinion

Justify your answer.

Prospective Teachers' responses

Scientific orientation	Correct N=4	Incorrect N=2	Irrelevant N=1
Technological orientation	Correct N=3	Incorrect N=5	Irrelevant N=2
Theoretical orientation	Correct N=1	Incorrect N=6	Irrelevant N=9

Typical Responses by the prospective teachers.
1. The aluminium foil is a heat conductor. So heat will be transferred from our hands to the snowball and raise a little its temperature.
2. The temperature of snowball does not change as long as the ball remains in the current phase. The snowball temperature will change as soon as it will start to melt.
3. The indication on the thermometer will be 0ºC, because the aluminium foil is a heat conductor.

Question 6. (Hypothetical Experiment)

Using an experimental arrangement (it was set up by the instructor) students a thermometer that measures temperature within a range from -10ºC to 150ºC. Students fix the Bunsen burner to low fire and put on it a Pyrex containing 300 ml of water. The initial temperature of the water is 20ºC. They were asked to take measurements every half-minute. In the first half the temperature rises to 31ºC, after the second half it rises to 42ºC and after the third half it reaches the 53ºC. They were asked to complete the following table:

t(min)	0	0,5	1	1,5	2	2,5	3	3,5	4	4,5	5	5,5	6	6,5	7	7,5	8	8,5	9	9,5
T(ºC)	20	31	42	53																

(t: time & T: temperature)

Prospective Teachers' responses

Scientific orientation	Correct N=4	Incorrect N=2	Irrelevant N=1
Technological orientation	Correct N=2	Incorrect N=2	Irrelevant N=6
Theoretical orientation	Correct N=1	Incorrect N=4	Irrelevant N=11

Typical Responses by the prospective teachers.
1. At 108ºC, the temperature will be kept steady.
2. Temperature will rise continuously

Question 7. Using the previous experimental arrangement, as the water boils we increase the fire abruptly. What do we observe in the temperature indicated by the thermometer?

a. The temperature will increase significantly (dramatically)
b. The temperature will increase slightly
c. The temperature will remain the same
d. In the beginning it will increase significantly, but afterwards it will remain constant at a somewhat lower level
e. I have no opinion

Justify your answer.

Prospective Teachers' responses

Scientific orientation	Correct N=5	Incorrect N=2	Irrelevant N=
Technological orientation	Correct N=4	Incorrect N=4	Irrelevant N=2
Theoretical orientation	Correct N=2	Incorrect N=7	Irrelevant N=7

Typical Responses by the prospective teachers.
1. The water boils always at 100ºC. So, the temperature will not change, even if I will increase the fire.
2. Én the beginning the indication on the thermometer will rise over 0ºC. Then, it will get stable somewhere lower. This happens, because when the water boils the temperature.
3. Due to the transition of state.

Question 8. According to your opinion what is contained inside the bubbles of boiling water? a. Steam b. Air
c. Oxygen and hydrogen in the gas phase d. They are vacant

Justify your answer.

Prospective Teachers' responses

Scientific orientation	Correct	Incorrect	Irrelevant
	N=1	N=4	N=2
Technological orientation	Correct	Incorrect	Irrelevant
	N=1	N=4	N=5
Theoretical orientation	Correct	Incor rect	Irrelevant
	N=0	N=3	N=13

Typical Responses by the prospective teachers.
1. The oxygen and hydrogen release in the air, because the temperature rises.
2. As the water consists of oxygen and hydrogen its bubbles contain the same substances.
3. The water bubbles are created by the collision of molecules as they try to change from the liquid state into steam.
4. Because it is water changed into steam.

Question 9. (Hypothetical Experiment)
We use two quite similar containers. We drop 1 litter of water to the first container and 1 litter of oil to the other. We leave them in the room for the whole night. The room temperature remains constant. The next day we measure the temperature of the two liquids. What shall we conclude?
a. The water temperature will be higher
b. The oil temperature will be higher
c. Both liquids have the same temperature d. I have no opinion

Justify your answer.

Prospective Teachers' responses

Scientific orientation	Correct	Incorrect	Irrelevant
	N=2	N=3	N=2
Technological orientation	Correct	Incorrect	Irrelevant
	N=2	N=4	N=4
Theoretical orientation	Correct	Incorrect	Irrelevant
	N=2	N=6	N=8

Typical Responses by the prospective teachers.
1. The oil's temperature will be higher because oil is thicker than water.
2. Q=L. m, where L depends on the nature of a liquid. A liquid Q increases when L increases.
3. The water temperature will be higher, because oil is a thicker liquid. Therefore, the transferring of heat through oil becomes more difficult.

Question 10. (Hypothetical Experiment)
We have two quite similar Pyrex containers. We drop 200 ml of running water in the first container. The water's temperature is $T_1=20^oC$. We drop 200 ml of warm water in the second container. The water's temperature is $T_2= 70^oC$. Then we drop the water of the first container to the second one and mix (it) very well.
What will be the temperature T_f of the final mixture?
a. $T_f = T_1+T_2=90^oC$
b. The temperature of the mixture will be equal to the higher temperature $T_f=70^oC$ c. $T_f=45^oC$ d. $T_f = T_2-T_1=50^oC$
e. The temperature of the mixture will be equal to the lower temperature $T_f=20^oC$ f. I have no opinion
Justify your answer.

Prospective Teachers' responses

Scientific orientation	Correct	Incorrect	Irrelevant
	N=6	N=1	N=0
Technological orientation	Correct	Incorrect	Irrelevant
	N=5	N=5	N=0
Theoretical orientation	Correct	Incorrect	Irrelevant
	N=4	N=6	N=6

Typical Responses by the prospective teachers.
1. The temperature will be 45^o0, as the final mixture reaches thermical equilibrium.
2. Because cold water is mixed with warm water and their mixture will reach the average temperature.
3. The temperature of the final mixture is equal to the difference: Äèfinal =è2 - è1= 50^oC.

CONCLUSIONS

In this study we have attempted to investigate the prospective teachers' attitudes on the issues and concepts that relate to heat and heat transfer. We consider worth mentioning that all of the prospective teacher students have been taught the concepts of heat during lower secondary school (7-9 grade), on a descriptive level. At grade 10 they have been taught that heat is a form of energy.

At grade 11, the students that selected the technological and scientific orientation have been taught the thermodynamic laws, thermal engines and kinetic theory of gases.

At grade 12 there is no any reference to concepts related to heat and thermodynamics.

The results reveal the fact that the Scientific orientation students perform better even though they do not seem to do well in the experiments and the procedures that involve description of the natural phenomena, contrary to the fact that they have all been taught such procedures in lower secondary school. It also appears that the one hour teaching in the laboratory was not effective enough as far as the description of the phenomena is concerned, an issue which remains to be further investigated.

Often the laboratory activities consist of simply verifying a principle or a law that has been learned in lecture and completion of the laboratory simply requires following a set of rules to get to the end result. In this framework the discovery learning is quite missing (Thacker, 2003). We suggest that the role of lab work must be reinforced with the inclusion of guided discovery and simulation experiments using the advances of information and communication technologies leading to the increase of lab skills.

The descriptions of prospective teachers' conceptions should also arouse awareness and sensitivity concerning the appropriateness and the effectiveness of science teaching at the primary and secondary level and probably must lead to a whole re-engineering of the curricula leading to more effective teaching sequences and practices.

(Valanides, 2000). Ìéá óçìáíôéêÞ ðáñÜìåôñïò ðñïò ôçí êáôåýèõíóç ôïõ In addition, a most significant factor in relation to the re-engineering of the curricula is the adaptation of the teaching methodology to the prospective teachers taking the pupils' misconceptions into account and the use of strategies for altering (changing) them (Maija Ahtee & Jane Johnston).

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Using of active educational strategies and methods - the way to improve the quality of science education

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Abstract
There are various problems in most countries with the quality of science education. One of the reasons on this situation is that the secondary school and university teachers sometimes do not manage properly the system of modern teaching methods to get the good level of student's knowledge and skills. In this work the modern system of active teaching and learning methods is analyzed. This system consists of different parts: educational methods, active strategies for the problem solving, pedagogical tools for modern evaluation and assessments, the computer educational software and Internet, modern textbook and another parts. The proper use of this system by teacher allows them to get necessary level of student's knowledge and abilities.
Key words: *active methods, science education, quality*

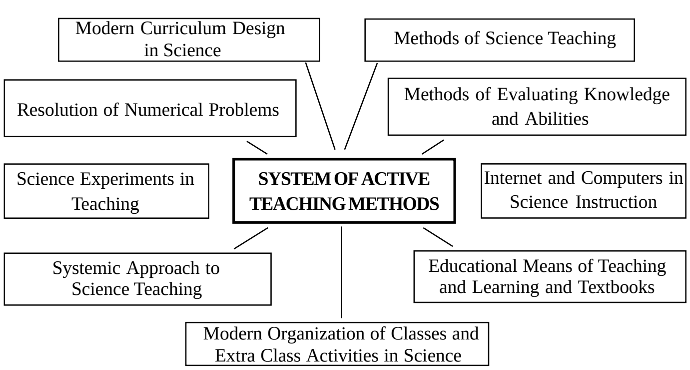
INTRODUCTION

It's known that the teaching of natural sciences is a very important aspect of education in the secondary and university levels of any country. Physics, Chemistry, Biology, Mathematics occupy the predominant place among natural sciences because they represent the base for the present and future development of industry as well as other parts of society. For this reason, the quality of knowledge and abilities in science of the students in the secondary school and university is very important, not only for their own success but also because it has a direct impact on the solution of environmental, industrial, cultural, and other key problems of modern life.

METHODOLOGY AND RESULTS

The educational practice shows that natural sciences are difficult for students and one of several reasons for this situation is that the teacher must use a range of appropriate teaching methods from the different national and international educational approaches in the classroom to achieve effective learning and he/she does not always have the necessary methodological bases to use these methods. Another problem of science instruction is that the teacher must teach students how to use modern learning methods in their systematic individual and group work to reach the required level of knowledge, abilities and skills (ORLIK, 2005).

To fulfill the modern requirements in pre-service and in-service science teacher preparation for the secondary school and university the following system of modern active teaching and learning methods is recommended (ORLIK, 2002):



The system is developed on the base of rather long author's professional work as a teacher of science and chemistry in different educational systems in Europe and some American countries (ORLIK, 2002).

The main objective of this system is to provide science teachers of the secondary school or university with the necessary summary of modern strategies and methods of teaching and learning. They can explore and adapt then to their students. We know that the principles and general methods of this subject are the same for the high school and the university. For example, for both levels we use explanations, the resolution of problems, laboratory and class experiments, the blackboard, computers and other methods and means. Clearly the science methodology has essential differences in the two levels of instruction and in the depth of courses, but not in main educational goals and objectives. Also, the basis for the general methods is the same.

The most essential parts and subsystems of this system are:

1. Modern Curriculum Design in Science

In many educational centers, teachers design their own science curriculum, so knowledge of the basic principles of this design and the corresponding examples can be very helpful in improving their teaching. For instance a very important problem for science teaching is analyzed: the place of the traditional curriculum and traditional methods in teaching and learning.

2. Methods of science Teaching

The most successful of the traditional and modern teaching methods must be used: active methods of teaching, asking questions, discussions method, investigative, heuristic and problemic methods, modeling and analogies, active methods of learning, principles of the motivation of the students and homework in teaching and learning.

3. Resolution of Numerical Problems

There are the different parts of the numerical problems solving methodology: typology of numerical problems in Physics, Chemistry and Mathematics: mathematical knowledge to solve problems, general resolution methods of problems, use of the different kind of calculations in solving, use of algorithms, visual algorithms and heuristic methods in the solution of problems.

4. Methods of evaluating knowledge and abilities

The contents of this subsystem is: the objectives and needs of the assessment and evaluation of knowledge and abilities, traditional methods of control, evaluations tests, evaluation of high level skills, the portfolio, open book exams and exams at home, short exams, use of the computers for evaluation and self-evaluation, qualitative methods and the integral strategies and so on.

5. Science Experiments in Teaching

The are different part of this subsystem: safety in the Physics, Chemistry and Biology teaching, methods of doing the science experiment in the classes, types of the experiment (demonstrative, student experiments in the teaching, minilaboratories, etc.), different types of traditional and modern