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Paper Title: A SURVEY OF THE FINNISH PUPILS´ CONCEPTIONS ABOUT THERMAL PHENOMENA

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Scott et al. (1992) have reviewed teaching strategies used to promote conceptual change. They have identified two main groupings, of which the one is based on cognitive conflict and the other on the development with the science point of view. The latter strategy focuses on the design of appropriate interventions by the teachers to provide "scaffoldings" for new ways of thinking. Stavy (1991) refers to the paper by Schollum et al. (1981) who in teaching about force started their instruction based on the conception held by many children that objects move forward because there is "something" in them that keeps them moving. They introduced the idea of momentum for this "something", and subsequently the term force for pushes and pulls that act on objects. Stavy (1991) herself reports about the study in which the students discarded their misconception about conservation of matter in the case of the evaporation of colourless acetone when they were first shown the evaporation of visible iodine.

The study reported in this paper is one of the first attempts to find out what kind of conceptions the Finnish secondary school students (from 7th to 9th grade, 14 to 16 years of age) have about thermal phenomena. According to the curriculum heat is taught as a subject partly in the seventh and partly in the ninth grade. The changes in the state of water have been discussed in biology in the third grade with the guidance of a class teacher. The research problem could be stated as, What kind of aspects do the pupils pay attention to in the connection of melting, boiling and heat exchange? Is there any indication about the similar type of confusion between the concepts of temperature and heat as there is between the concepts of momentum and force? The ultimate aim would be to find a possible order for teaching thermal concepts and phenomena.

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A SURVEY OF THE FINNISH PUPILS´ CONCEPTIONS ABOUT THERMAL PHENOMENA

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INTRODUCTION

The importance of the teachers to know and take into account the pupils´ conceptions as the starting point in teaching is well recognised from numerous studies. This knowledge is needed because only when the teachers realize what their pupils´ really think about various phenomena and how little effect the traditional teaching independent of its quality has on the pupils´ understanding, they start to experiment with new teaching strategies. The area of heat and temperature is very useful in this respect (see e.g. Brook *et al*., 1984; Erickson and Tiberghien, 1985, Osborne and Freyberg, 1985). The pupils have met most of the thermal phenomena in their everyday life, their use of the scientific terms is mixed with everyday meanings, and they also think they know all about these familiar phenomena.

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MELTING

In the 7th grade first time in formal physics teaching the concepts of temperature and heat are introduced and connected to the changes of state. The 9th grade pupils should know that all solids except amorphous materials have a characteristic melting point, melting needs heat energy and that during the melting process there is no change in temperature. At the ninth grade the pupils are introduced the ideas of latent heat qualitatively as well as particle theory. The main purpose with the first task was to find out to what extent the pupils understand what happens during melting.

Task 1 Describe the circumstances which you think are needed for ice to melt?

The question was tried to have a fairly general formulation in order to encourage the pupils to use their own descriptions instead of trying to remember what was said in the text book. The answers were classified into six categories.

Scientific understanding would include both the ideas of melting at constant temperature and the need of heat for melting to take place. However, there was only a couple of answers at the 9th grade which reached this level, "*Warm circumstances are needed as heat melts ice into water with same temperature.*" Therefore all answers indicating that heat is needed where classified into category A: Heat mentioned even that they contained obscure statements, like "*Ice melts when it is warm. Immediately when ice is somewhere else than in coldness it starts to melt slightly. Heat energy will flow into it.* " The answers in which the melting point was given as 0 °C were classified into the second category B.

More ambigious verbal expressions were classified into the third category C: Everyday notions or common knowledge. Very often the pupils referred to the beginning of spring, warm weather and sunshine. "*When it is warm enough.*", "*In spring, when it becomes warm snow and ice will melt.*" In some of these answers the interaction of ice with air, water, warm space like room or cooking plate was indicated. It was not always possible to make a clear distinction whether the pupils meant that weather had to be warm enough or the air in contact with the ice had to be warm as in Finnish the word air can also be used to mean weather. In some cases heat and coldness were percepted as opposite concepts like "*Water freezes when there is frost so ice has to melt when it is warm.*"

Table 1. Distribution of the answers by percentage to the question "Which kind of circumstances do you think are needed for ice to melt?"The categories are: A. Heat mentioned, B. Melting point 0 °C, C. Everyday notions or common knowledge, verbal expressions, D. Ice melts when the temperature is slightly above 0 °C, E. Ice melts when the temperature is equal to or above room temperature, F. Meaningless or no response.

Grade/ number	A Heat	B 0 °C	C verbally	D > 0 °C	E ≥ RT	F
7 /197	2.0	13.7	36.5	30.5	14.2	3.0
9 /195	8.2	11.3	30.3	42.6	4.6	3.1

The answers in which temperature for melting was suggested to be above 0 °C were divided into two categories slightly above 0 °C, in a few cases even +4 °C (category D), and room temperature or even higher (category E). Categories C and D contain also the answers according to which some of the pupils (5% in both grades) may think that the temperature of ice is always the same, most probably 0 °C like "*Air warmer than ice is needed to melt ice.*".

It is interesting to notice that even those pupils (less than 20%) who seem to understand about melting mention only one aspect of it either heat or melting point. Altogether, it was obvious that most pupils had not internalized a scientific way of thinking or expressing themselves. After two years of formal teaching in physics and chemistry very little is learned. There is no indication of the pupils trying to analyze the factors effecting in melting. They do not connect melting to heating of solids or liquids. Everyday knowledge and language seems to have a strong influence on the way they think. Their answers show a superficial level of understanding. They miss the qualitative and quantitative key questions about melting like "Why does not temperature rise during melting even that heat is brought in all the time?" or "How much heat is needed to melt a certain amount of ice into water with same temperature?"

Task 2 Predict the volume and the mass of water formed from the given piece of ice.

The main purpose with the second task was to find out to what extent the pupils have percepted the idea of conservation of mass. This fundamental idea is not much stressed in the text books perhaps because it is taken as self-evident. However, it is the basis of chemical reactions. Therefore, one would expect an increase in understanding with the ninth graders who have studied chemistry a whole year in grade 8.

Teachers were asked to start a demonstration with melting ice to the whole class. They measured the volume and mass of a piece of ice with the pupils and while waiting the ice to melt the pupils filled into the questionnaire what they predicted would be the volume and the mass of the water formed from the ice. After collecting the answers the teachers carried out the demonstration. The pupils´ predictions are shown in Table 2

Table 2. Distribution of the answers of the 7th and 9th graders by percentage in the tasks predicting the change in mass and volume when a piece of ice melts into water.

	Change in mass		Change in volume	
Grade/number	7th /197	9th /195	7th /197	9th /195
No change	52.3	47.2	46.2	21.5
Increases	14.7	25.1	24.9	22.6
Decreases	24.9	24.1	22.3	51.3
No response	8.1	3.6	6.6	4.6

About half of the pupils in grades 7 and 9 have not realised the fundamental status of the conservation of mass. The change in numbers from grade 7 to 9 is not statistically significant so that it can be said that studies in chemistry have not helped in this respect. In grade 9 the rest of the pupils are distributed more or less equally into groups according to increase or decrease in the mass. When the estimates for the mass of water were compared with the original value of the mass of the ice block, about 17% of the 9th graders estimated that the mass decreases more than 10%.

As to the change in volume half of the 7th graders thought also it to stay constant whereas half of the 9th graders and fifth of the 7th graders predicted the volume of the water to be less than the original volume of the ice block. Slightly over 60% of them estimated the change to be fairly small (less than 20%). The 9th graders have obviously learned that the density of ice is smaller than the density of water or more probably they have been told about the damages what freezing water makes when it expands – at least this should be common knowledge in a cold country like Finland.

In order to study further the relations between the pupils´ responses the percentages of the different answers were organized into a crossbreak, see Table 3.

Table 3. Relation between the pupils´ responses on the changes in the mass and volume when a piece of ice melts into water.

a) 7th grade

		VOLUME			
		No change	Increases	Decreases	Num/%
MASS	No change	68.0 35.5	16.5	14.6 34.1	103/52.3
	Increases	10.3	58.6 8.6	16.3 18.2	29/14.7
	Decreases	28.6	24.5	42.9 47.7 10.7	49/24.9
	Num/%	91/46.2	49/24.9	44/22.3	197

b) 9th grade

		VOLUME			
		No change	Increases	Decreases	Num/%
MASS	No change	37.0 17.4	14.1	47.8 44.0	92/47.2
	Increases	8.2	51.0 12.8	40.8 20.0	49/25.1
	Decreases	8.5	10.6	76.6 36.0 18.5	47/24.1
	Num/%	42/21.5	44/22.6	100/51.3	195

At the 7th grade, two thirds of the pupils who think that mass stays constant when ice melts into water – that means a third of all the seventh graders assume that the volume of the ice does not change either. Respectively, slightly over half of those who expect the mass of water to increase also predict the volume to increase, and similarly slightly less than half of those who expect the mass to decrease also predict the volume to decrease. In both cases this is about 10% of the whole amount of the pupils. On the other hand, about 15% of those pupils who believe in the constancy of the mass expect the volume of the ice to decrease. This means that only 7.6% of the seventh graders have predicted both changes correctly. In Table 3, also the percentages from the number of the pupils predicting the volume of the ice to decrease in the melting process are shown. Almost half (47.7%) of those who think that the volume will decrease also assume that the mass will decrease as well.

There is a clear improvement in the knowledge of the ninth graders. Now only one third of the pupils who think that mass stays constant when ice melts into water suggest the similar behaviour in the case of volume. Only about every fifth (22.5%) of the ninth graders has a sound understanding about the changes in mass and volume. Table 3 indicates that the pupils seem to have a tendency to assume the same kind of behaviour for both variables, mass and volume. It is not easy for the pupils to percept which rules are general ones and which rules can be applied only to a specific phenomenon.

Erickson and Tiberghien (1985) introduced the following task to the pupils after teaching when it was stressed that temperature stays constant during the melting process. However, a considerable portion of the pupils interpreted the melting point to be the maximum temperature the substance can have when it is heated.

Task 3 Liisa puts a piece of zinc in an oven at 1000 °C. She reads the temperature of the zinc every minute. She gets the following readings: 30 °C, 70 °C, 200 °C, 420 °C, 420 °C, 420 °C, ...
1) Why does the thermometer have several readings of 420 °C?
2) What happens when Liisa goes on reading the temperatures? Does the temperature of the zinc rise to 1000 °C or does it stay at 420 °C?
Give your reasoning.

The Finnish results are collected in Table 4. From the written answers to the first question it was clear that about 20% the pupils in both grades 7 and 9 understood that zinc is melting and its melting point is 420 °C. In the best answers it was also mentioned that zinc needs heat energy for melting. The answers to the second question showed that these pupils understood that after the change of state the temperature of zinc will reach the temperature of the oven (and in a few cases it was suggested that zinc may vapourize before that). This means that they had internalized the concept of thermal equilibrium as the basic idea. But only about 20% of the pupils had a sound understanding of melting process. There was no improvement in understanding from grade 7 to 9 even that the pupils had studied the particulate nature of matter in chemistry in grade 8.

About 40% of the pupils both in 7th and 9th grade stated that zinc cannot warm up more referring to the possibility that 420 °C is the highest possible temperature for zinc. They reasoned with arguments like "*temperature of zinc* *stays all the time at 420 °C as it does not warm up any more*" or "*it cannot attach more heat*".

Table 4. Distribution of the answers by percentage to the questions 1 and 2 in task 3 (Q1, Q2). The categories are: A. Recognition and understanding of the melting process, B. 420 °C is the highest possible temperature for zinc, C. Zinc is boiling at 420 °C, D. Concrete explanations or misunderstanding of melting, E. Meaningless or no response. At the 7th grade there were 74 pupils and at the 9th grade 191.

		A	B	C	D	E
7th	Q1	18.9	41.9	8.1	13.5	17.6
	Q2	20.5	38.4	8.2	11.9	21.9
9th	Q1	22.0	39.0	13.1	14.7	11.0
	Q2	20.8	32.3	18.2	21.7	7.3

About 10% of the 7th graders and slightly more at grade 9 spoke about boiling, like "*zinc will stay all the time at 420 °C, it is liquid and just goes on boiling*". In some cases the pupils may have simply confused the terms melting and boiling. But in some cases the pupils may have understood that zinc is now liquid but because the temperature is so high zinc must be boiling like water and therefore vanish from the oven. In other words, they have associated hot liquid with boiling water and skipped the stage when liquid is heated between its melting and boiling points.

About 15% of the pupils gave to the first question a conrete reason like "*thermometer does not show more*", "*the oven is not functioning properly*" or "*the temperature of the oven is not high enough*". Most of these pupils changed their answers in the second question to the statements like "*the temperature will stay at 420 °C as zinc will melt*". Only about 5% of conrete explanations were left.

BOILING

In the first task 121 seventh grade and 69 ninth grade pupils were asked to describe boiling water before they had studied the subject of heat. In the instructions the teachers were told to let the pupils first observe the boiling of water and then answer the following two questions.

> *Task 1 When water is let to boil for a long time, the water in the beaker decreases.*
> *1) What has happened to the vanished water?*
> *2) When water is boiling, you can see bubbles in the beaker. What do you think the bubbles are?*

The distribution of the answers are collected in Table 5. The answers to the first question were classified in category A when the gaseous state of water was described, like "*Water has changed into steam.*" and in category B when only the name of the process was mentioned, like "*It has evaporated*". In very few answers (about 4%) the change of state from liquid to gas was pointed out. It is interesting to notice that the first question did not help the pupils in the second question. Learning has been very superficial. The pupils have not learned to combine different facts. Due to learning the ninth graders talk more often about vaporisation instead of steam. As in the connection of task 1 of melting the pupils do not seem to ask themselves any questions like "How do I know it?" or "What kind of evidence is there to support my statement?" They more or less recite a term which they think will suit to this case. Category E contains the answers with meaningless or no response also in the second question.

Table 5 Distribution of the answers by percentage in the task on observations of boiling water and description of the contents of the bubbles.

	Category	7th grade/121	9th grade/69
What does happen to the boiling water?	A	76	59
	B	22	40
	E	2	1
What are the bubbles?	A	12	7
	B	46	45
	C	10	17
	D	10	15
	E	22	17

There is almost no difference in the answers to the second question between the 7th and 9th graders. Around 10% understood that the bubbles are gaseous water, steam (category A). Nearly half of the pupils were convinced that the bubbles contain air (category B), like "*The bubbles are air and water. Air has somehow got under the water and thin film of water stops air leaveing before the bubble breaks.* " Heat, oxygen, hydrogen and even carbon dioxide were also mentioned (category C). Some of the pupils equalized also oxygen and air. "*The bubbles are formed from oxygen in water. They rise up and disappear. They are air.* " Sometimes there was some other idea behind the reasoning, e.g. the lightness of hydrogen. "*When hydrogen atoms separate from H_2O molecule they rise up.* " Some of the 9th graders tried to apply atomic explanation to boiling but usually wrongly, like

"Water is bubbling and waving, because the atoms tremble the more the hotter it is." or *"Heat is movement of electrons. When water is boiling in a beaker, electrons are busily moving in water atoms. Heat is transferred from the plate to the water in the beaker."* Around 10% of the pupils only described how the bubbles behave in water without mentioning what the bubbles are (category D). The seventh graders were more cautious and gave response (19%) whereas the ninth graders stumbled to erroneous explanations (11%) like "*The bubbles are formed by the hotness*".

The understanding of the constancy of the boiling point of water was tested with the aid of the following three questions introduced by Andersson and Renström(1979). The tests with given alternatives were given to seventh and ninth grade pupils after they had studied the subject of heat according to the corresponding curriculum In the instructions the teachers were asked especially to stress the importance of reasoning. The results are collected in Table 6 together with the Swedish results.

Task 2 1) *The effect of boiling time on boiling point*
The beaker is on the hot-plate which is set at position 4. After five minutes water starts to boil. The thermometer shows the temperature to be +100 °C. The switch is kept at position 4 while water is boiling. What does the thermometer show five minutes after boiling started?
2) *The effect of amount of water on boiling point*
There is boiling water in two beakers, 1 litre in beaker A and 3 litres in beaker B. In beaker A the thermometer shows 100 °C. What is the temperature in beaker B?
3) *The effect of heating power on boiling point*
The beaker is on the hot-plate which is set at the position 3. After five minutes water starts to boil. The thermometer shows the temperature to be +100 °C. The switch is now set at a stronger heating position 6. What will happen to the temperature reading?

Majority of the pupils did choose the alternative No Change in each case. However, 40% of the 7th graders and 30% of the 9th graders had doubts about the constancy of the boiling point when the amount of water and heating rate were varied. They had not fully understood the content of the expression "the boiling point of water is 100 °C". Andersson and Renström (1979) point out that in teaching the variables which have an effect on boiling point like pressure and impurities are mentioned whereas the factors which have no effect are passed by. The same is true according to the Finnish textbooks. This means that very little attention has been paid to one of the central ideas in physics i.e. to look for the invariancy of the variables

Table 6. Distribution of the answers by percentage in the tests concerning the effects of 1) boiling time, 2) amount of water, and 3) heating rate on the boiling point of water. The Swedish results are from the work of Andersson and Renström (1979).

1) *How does the boiling point of water vary with heating time?*

	Finland		Sweden	
Grade/number	7th/80	9th/197	7th/138	9th/120
Increases	13	10	24	16
No change	83	83	73	81
Decreases	2	6	4	2

2) *How does the boiling point of water vary with the amount of water?*

	Finland		Sweden	
Grade/number	7th/80	9th/307	7th/138	9th/120
Increases	4	2	3	1
No change	59	70	63	85
Decreases	38	25	33	14

3) *How does the boiling point of water vary with heating rate?*

	Finland		Sweden	
Grade/number	7th/80	9th/308	7th/139	9th/120
Increases	41	29	63	54
No change	59	69	24	43
Decreases	0	1	3	2

The exceptional behaviour of water at the boiling point was not realised by the pupils who in the first alternative Increases reasoned that "*More and more heat is brought into the water all the time*". The well-known misconception during the early years about temperature depending on the amount of water may have lead many pupils to mix the concepts of temperature and heat. Two pupils reasoned in question 2 like "*A higher temperature is needed to boil a bigger amount of water*" and "*As the other beaker contains more water, it also needs more energy to boil it*". Both of them chose the alternative Increases. These pupils seem to have similar difficulties in differentiating the gestalts of temperature and heat as many pupils have with momentum and force. Due to the Finnish language the words heat and temperature were often misused like in the reason of the right choice No Change "*Heat does not rise above 100 °C but water starts to evaporate*".

The everyday experiences with cooking plates confused the pupils´ thinking. This became evident especially in the third test. Already in the first test nearly a quarter of the pupils who had chosen the alternative No change reasoned like "*If the position of the switch is not changed the temperature will stay the same*". Again it was clear that some of the pupils neither made any distinction between the words or concepts of heat and temperature nor realised the possibility of the change of state when the substance is heated as in the examples "*If at the position 3 the plate gives 100 °C, so at the position 6 it should give 200 °C*" or "*The water warms up because it stores heat*".

When the answers of the girls and boys were compared there was a statistically significant difference (at 0.1% level) in the third question, see Table 7. When the reasons were inspected in more details it was found that 55% of the girls and 49% of the boys argued for the alternative No change simply by "*The boiling point of water is 100 °C*". However, 41% of the boys paid attention to the change of state whereas so did only 22% of the girls. Furthermore, 23% of the girls mentioned the position of the switch whereas only 10% of the boys. It looks like that the boys reach a higher level of explanation more often while the girls are satisfied with a more concrete explanation.

Table 7. Comparison of the answers of the girls and boys by percentage in the tests concerning the effects of 1) heating time, 2) amount of water, and 3) heating rate on the boiling point of water at the ninth grade.

	Heating time		Amount of water		Heating rate	
	Girls/93	Boys/99	Girls/135	Boys/160	Girls/136	Boys/164
Increases	9	11	1	2	40	20
No change	86	82	67	73	59	76
Decreases	5	4	30	23	1	1

HEAT EXCHANGE

The pupils´ understanding of the concept of thermal equilibrium was tested by a quantitative test introduced by Stavy and Berkovitz (1980).

Task 1 What is the temperature of the mixture, when equal amounts of water having temperatures of 10 °C and 70 °C , respectively, are poured into the same vessel?

In Table 8 the results from the 7th and 9th grades are compiled together with the ones from primary grades 4 and 6. The test turned out to be really difficult. In the lower grades the pupils tend to add and in the higher grades to subtract the given temperature readings. The answer 70 °C was also fairly popular among the 9th graders, 15.9% of them offered it as their estimation. Only 10% of the 6th graders estimated the value 40 °C correctly. Whereas nearly 20% of the 7th graders and 35% of the 9th graders succeeded in calculating the mean value.

Stavy and Berkovitz (1980) found a conflict between reasoning when they asked children aged 4 to 10 years to predict resultant temperatures in qualitative and quantitative situations when equal amounts of hot or cold water were combined. When Driver and Russell (1982) investigated the ideas of children in England and Malaysia they found that by age 14 about four-fifths of the students understood temperature as an intensive quantity. The common error with the other students was to add the temperature readings when combining equal amounts of water having the same temperature. I have carried out a similar study in Finland and found that the portion of the pupils percepting temperature as a characteristic property of water increases from 30% to 70% from grade 2 to 6. In grades 2 to 4 about third of the pupils tended to connect temperature with the amount of water or they used it as a measure of heat (hotness or coldness). The latter intepretation increased in upper grades. In the 7th grade most of the pupils have an understanding of the quantitative temperature scale and they also realise that thermal interaction of the system with its surrounding does not play important part in combining water quickly. According to Driver and Russell (1982) 70% of the 14 year old pupils in Leeds and 92% of those in Penang, Malaysia predicted the resultant temperature sensation to be warm when equal amounts of hot and cold water were combined. With this result in mind the pupils seem still to have difficulties with the qualitative and quantitative temperature scales. This shows how big the step is from the qualitative level of understanding to the quantitative level. Before reaching the quantitative level the pupils have to percept the idea of thermal equlibrium and understand the difference between the concepts of temperature and heat.

Table 8. Comparison of the distribution of pupils´ answers by percentage in the task of combining equal amount of water at different temperatures in the grades 4 to 9.

Grade/number	4th/206	6th/174	7th/202	9th/138
80 °C	52.2	32.2	18.0	10.1
60 – 80 °C	19.9	14.8	9.0	15.9
60 °C	13.7	34.2	48.9	37.0
< 60 °C	11.7	15.3	24.1	37.0

A clear difference was found in the answers of the boys and girls in this task. The boys managed clearly better than the girls in the quantitative task in estimating the average value of the temperature both in the 7th and 9th grade (see Table 9). The girls made a better progress but even so in the 9th they managed worse than the boys in the 7th grade.

Table 9. Comparison of the distribution by percentage of the boys and girls giving the answer as 80 °C or estimating the temperature to be less than 60 °C in the task of combining equal amount of water at different temperatures .

Estimate	7th grade Boys/78	7th grade Girls/92	9th grade Boys/109	9th grade Girls/127
80 °C	7.7	30.4	6.4	11.8
< 60 °C	38.5	10.9	46.8	24.2

The aim with the last task was to find out which concepts the pupils use when explaining thermal interaction between a cold piece of iron and warm water. According to the curriculum and most of the textbooks the concept of heat capacity is not dealt in the secondary school level. As there is no information given in the task about the magnitude of the piece of iron or of the amount of water it is obvious that only qualitative understanding is required.

Task 2 Piece of iron with temperature of 0 °C is put into a vessel nearly full of water with temperature of 50 °C. Explain what will happen to the temperatures of the piece of iron and water. Give your reasoning.

Both of the ideas of thermal equilibrium and transfer of heat from the hotter object to the colder one are necessary for the real understanding. *"The temperatures will equalize because water will give up heat to the piece of iron. While the piece of iron warms up the water cools down."* A more common expression was like "*The piece of iron takes heat from water*". These answers were classified in the first category, Understanding of two main principles. The answers which contained either mentions about thermal equilibrium or about heat transfer were placed into the second category: Understanding of one main principle. Typical answers were like, "*The water will cool down and the iron will warm up as they will strive for the common temperature*" or "*The water will cool down and the iron will warm up because the water will give heat to the piece of iron*". The answers distributed almost equally between these alternatives. The answers in the third category, Common knowledge, are correct but do not contain any scientific expression, i.e. "*The water cools down and the iron warms up*". Neither the general principle of thermal equilibrium nor the concept of heat was used in the descriptions. They have no need to find a general explanation. The fourth category, Misconceptions, contains the answers with faulty ideas. Typical errors were e.g. to calculate the average of the temperature readings, "*The equilibrium temperature will be 25 °C.* ", or to think that one of the temperatures will stay unchanged for different reasons like, "*The temperature of the water will stay the same, as the temperature of the iron was 0 °C.*" or "*The piece of iron will warm up in hot water. The temperature of the water does not change.*" or "*The temperature of the iron will stay the same as iron does not warm up easily but the temperature of the water will decrease. The same if you put a piece of ice into warm water. It will cool down.*" The concept of coldness was also used in the explanations, like "*The piece of iron will give coldness to the water.*" In these examples heat and coldness are used as entities of their own. In some cases the transfer of heat was thought to be due to good heat conductivity of iron. Also the expansion of iron was thought to be the cause of its warming, "*The piece of iron will expand and the temperature of water will decrease. The cold iron will start to vibrate and it will warm up and the water will cool down*". Especially among the boys´ answers there were some in which the particulate nature of matter was tried to take into account but without success, "*The piece of iron will warm up and the water cool down as the electrons will slow down and speed up each others*".

Table 10. Distribution of the answers of the 9th graders by percentage in the task "A piece of iron is put into water". The categories are: A. Understanding of two main principles, B. Understanding of one main principle, C. Common knowledge, D. Misconceptions, E. No responses.

	A	B	C	D	E
Girls/106	11.3	25.5	22.6	37.7	2.8
Boys/111	6.3	36.0	30.6	21.6	4.5
Total/217	8.8	30.8	26.7	29.5	3.7

The results of this task are collected in Table 10. In some of the answers (less than 10% of all answers) the terms temperature and heat were mixed but as this can be at least partly due to the Finnish language it was not taken into account. Very few, less than 10% of the 9th graders were able to recognize the both main principles needed for good understanding. The "alternative views" are much same as those found by Duit and Kesidou (1988) like explaining the changes in temperature by properties of one or both bodies envolved. There was a statistically significant difference in the amount of misconceptions among the girls and boys.

CONCLUSIONS

Based even on the findings in this work it can be concluded that the pupils´ knowledge at the secondary school level about thermal phenomena is superficial. The majority of the pupils describe their observations using common knowledge and everyday language. They do not see the significance of a general explanation. The amount of science learning in physics and chemistry does not make almost any difference. This result is well known, for example Brook *et al.* (1984) conclude that "only a small proportion of students learn and use the accpted ideas with confidence". As the use of everyday expressions has so considerable influence on the pupils´ thinking, its effects have to be taken into account in teaching. In the connection of common discussions with the class the specific meanings of the scientific concepts have to be compared with common usage of the corresponding terms.

The pupils seem neither to have the skill to make good scientific questions which are needed to go further with the problem, to seek clarification, to invite more enquiry and to lead to investigations (see e.g. Fisher, 1990 and Harlen, 1988). A simple advice for the teachers is that they have to show the way by making both qualitative and quantitative questions. With the aid of these questions they may build a connection from the behaviour of the special simple phenomenon looked at in the science lesson to the general models, laws and theories. It is important to stress the central ideas like the conservation of mass, the importance to look after invariances like the constancy of melting and boiling points, thermal equilibrium and so on. These can act as the pivots on which one can always support one´s thinking when trying to clarify a complicated situation. For example, when the pupils study chemistry in grade 8 in addition to the particulate nature of matter they ought to have the idea that energy is needed for reorganisation of atoms and molecules. The same idea is used in melting and boiling. One has to be careful so that the great basic ideas are not screened by a large amount of detailed information. The main ideas should be used as Ausubel´s advanced organizers to explain, integrate and interrelate the new phenomena and concepts to the previously learned and familiar ones.

Many of the pupils who seem to understand the phenomenon tend to describe only one aspect of it. They seem to be happy one they have found one reason which could cause the observed event. The pupils have to learn to analyze events, which have more than one independent variables. Here the open investigations in which the pupils have to find a problem they are interested in, find all the factors which could contribute and decide which effects they want to clarify, and so on (see e.g. Jones *et al.*, 1992).

It seems obvious that the pupils should first obtain through ample experiences clear understanding of the concept of temperature (Sciarretta *et al.*, 1990). It would be interesting to start the instructions on heat building on students´ correct intuitive preconceptions e.g. heating with different heating rates different amounts of water and also other materials. In this connection it may be possible to introduce heat exchange also as a process of thermal interaction between two bodies (systems) with different temperatures. After that it seems logical that they should go on measuring changes in temperature e.g. heating water and ice and also other materials to find the exceptional behaviour of temperature in the changes of state.The concept of equilibrium temperature should be introduced fairly early so that it can be used as a basic idea. Finally, the quantitative aspects should also be brought into consideration though with care because the step from the qualitative level of thinking to the quantitative level is big and it needs time.

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