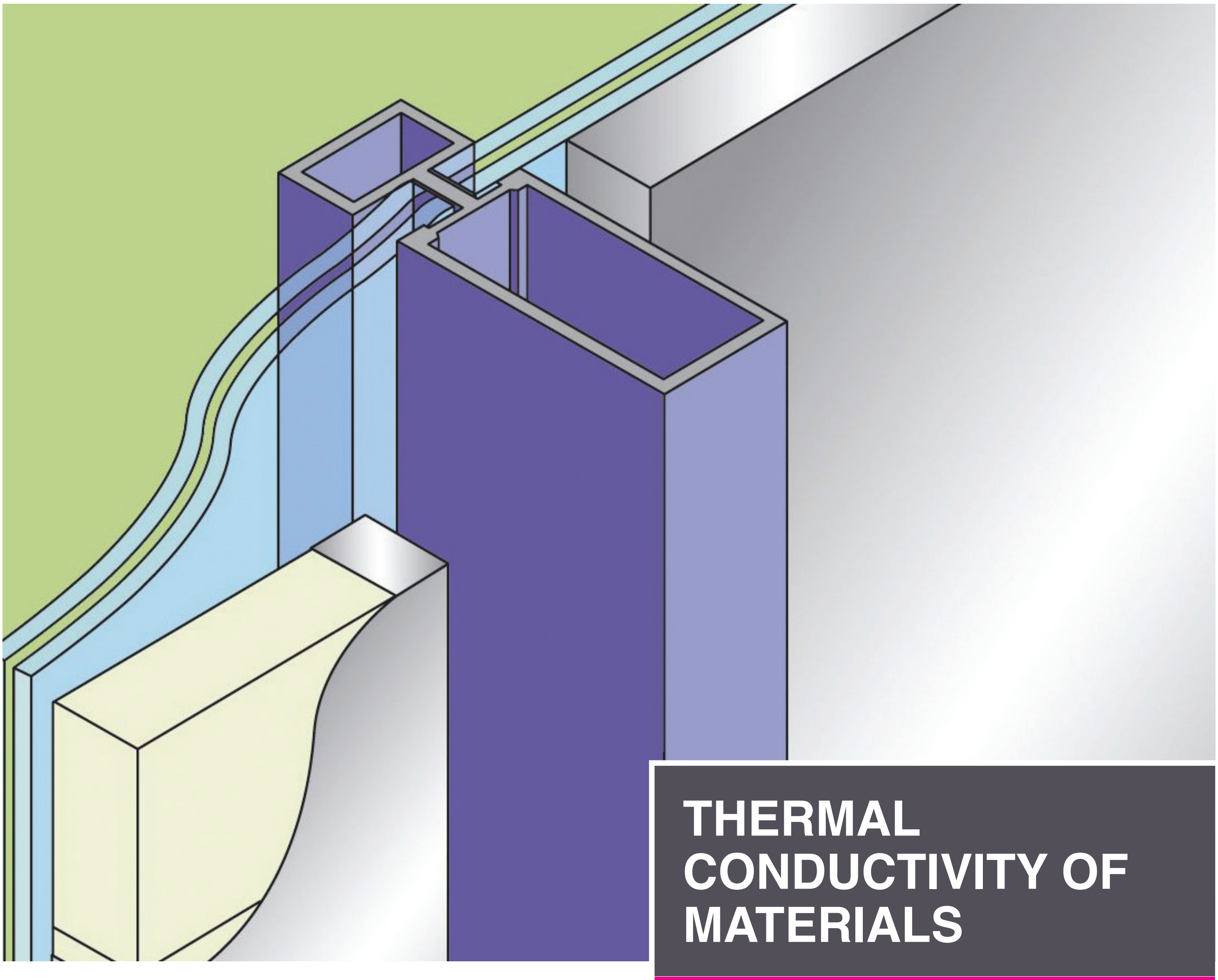

THERMAL CONDUCTIVITY OF MATERIALS

TEACHERS' MANUAL

ADAPTED VERSION

MATERIALS SCIENCE PROJECT

UNIVERSITY-SCHOOL PARTNERSHIPS FOR THE DESIGN AND IMPLEMENTATION OF RESEARCH-BASED ICT-ENHANCED MODULES ON MATERIAL PROPERTIES

SPECIFIC SUPPORT ACTIONS

FP6: SCIENCE AND SOCIETY: SCIENCE AND EDUCATION

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THERMAL CONDUCTIVITY OF MATERIALS

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A: DESCRIPTION OF STUDENT ACTIVITIES

A: DESCRIPTION OF STUDENT ACTIVITIES

UNIT 1: THERMAL CONDUCTION IN EVERYDAY LIFE

1.1. HOUSE INSULATION
1.2. CUPS FILLED WITH LIQUID

Student Level
14-15 years old

Learning Objectives

1.1. Identify the materials used to build different parts of a house.
Relate common life experience with the materials' property of being more or less thermally conductive.
Understand thermal insulation and heat transfer in solids.
Identify different materials that are thermal insulators.

1.2. Study thermal interaction of different materials.
Use experimental evidence to decide on an everyday problem about thermal conduction.

Recommended setting and pedagogical approach

1.1. Students work in groups. They share their answers every two questions and interact with all the class and their teacher.
It would be preferable to have on a table, pieces of glass, plastic, bricks, or any other object that is used for building a house.

1.2. The pupils work in groups in order to carry out an experimental investigation. There are 3 different experimental sets. Therefore, the pupils are split in 3 or more groups. If the number of pupils permits it, ($n_{group} > 5$ or $N_{class} > 15$), then there may be two teams assigned to each experimental set.

Important questions

1.1. What is thermal insulation and how can we understand thermal exchanges between environments at different temperature?
What are the differences as regards thermal insulation of the solids used commonly in houses?

1.2. How can one experimentally detect thermal conductivity of commonly used objects made of different materials?

Material resources

1.1. Pieces of glass, plastic, bricks, or any other object that is used for building a house.

1.2. 2 similar cups with cover: 1 made of glass and 1 made of plastic,[1] (1b:1 made of glass and 1 made of metal / 1c:1 made of plastic and 1 made of metal), 2 small glass basins, 2 laboratory thermometers, chronometer, water.

Hints and Tips
Refer to Teacher's Guide - Unit 1

1. *Separate worksheets should be printed for each team, similar to this one, the only difference being that the gray areas will be replaced by the yellow ones (WS_1b) or the blue ones (WS_1c).*

UNIT 2: MICROSCOPIC MODELS FOR THERMAL PHENOMENA

2.1. TEMPERATURE AND THE MICROWORLD
2.2. THERMAL CONDUCTION AND THE MICROWORLD

Student Level
14-15 years old

Learning Objectives

2.1. Be able to explore and give meaning to simulated microscopic models.
Understand the microscopic model for temperature in ceramics and metals.

2.2. Be able to use simulated microscopic models in order to make sense of macroscopic phenomena.
Be able to recognise the role of the lattice particles' vibrations as regards thermal conduction in ceramics and in metals.
Be able to recognize the role of free electrons in thermal conduction in metals.
Interpret thermal conduction in ceramic materials and in metals at the microscopic level.

Recommended setting and pedagogical approach

2.1. Pupils work in teams at the computer

2.2. Pupils, after the demonstration experiment, collaborate in teams of two and run computer simulations.

Important questions

2.1. How does temperature relate to lattice particles' movement in a ceramic, in a microscopic representation?
How does temperature relate to lattice particles' movement in a metal, in a microscopic representation?

2.2. Observe your teacher as he performs the experiment. He warms up, with two small candles, two bars; a metal bar and a glass bar. On top of both rods, and at the same distance from the end that is heated up, there are four small blobs of wax, placed at equal distances.
The wax, when heated up, will start melting
In which rod will the wax melt first?
What is the meaning of a "simulation "?
How does heat propagate? In ceramics? In metals?

Material resources

2.1. Computer Simulation: Microscopic Models: Lab 1

2.2. Computer simulations: Microscopic simulation Lab 4

Hints and Tips
Refer to Teacher's Guide - Unit 2

UNIT 3: FROM MATERIALS TO CATEGORIES OF MATERIALS

3.1. THERMAL CONDUCTION IN METALS
3.2. THERMAL CONDUCTION IN CERAMICS, PLASTICS, TEXTILES

Student Level

14-15 years old

Learning Objectives

3.1. Be able to detect the effects of thermal conductivity by means of experimental evidences
Investigate thermal conduction in different metallic bars.
Understand the use of different conductors in a house and in everyday situations.

3.2. Explore thermal conduction in ceramics, plastics and textiles.
Understand the potentialities of a virtual experiment.
Relate thermal conduction of different objects (same initial temperature), to the different time elapsed to reach equilibrium.

Recommended setting and pedagogical approach

3.1. The experiment is performed by students working in teams.

3.2. Pupils collaborate in groups of two or three in front of each computer.

Important questions

3.1. Do all metals have the same conductivity?
How can we perform an experiment to test the previous question?
Do every day phenomena provide evidence for differences in thermal heat conduction of different metals?

3.2. Do all ceramics have the same conductivity?
How can we interpret the result of a virtual experiment?
Do every day phenomena provide evidence for differences in thermal heat conductivity of different ceramics? Of plastics? Of textiles?

Material resources

3.1. 1 set of 5 rods (made of metals: aluminium, iron, copper and the alloys: bronze and inox), thermal paper, 5 small candles (tea lights), 1 magnet, 1 ruler, gloves; 1 book (up to 2 cm thick), erasers and pencil sharpeners (to stabilize the rods).

3.2. Virtual Experiments: Simulated Experiments: Cooling Lab 3, Lab 4 and Lab 5.

Hints and Tips

Refer to Teacher's Guide - Unit 3

UNIT 4: FACTORS AFFECTING THERMAL CONDUCTION

4.1. MATERIALS' CONDUCTIVITY
4.2. SURFACE AREA
4.3. THICKNESS

Student Level
14-15 years old

Learning Objectives

4.1. Understand the color codes of thermal photography.
Relate house thermal insulation to energy savings.
Establish all possible factors affecting design choices for a thermally insulated house.

4.2. Understand the role of a vessel's base surface as regards thermal conduction.
Be able to investigate on how the size of a vessel's base surface affects thermal conduction
Be able to infer an order relation between the vessel's base surface and thermal conduction.

4.3. Understand role of a vessel's wall thickness as regards thermal conduction.
Be able to investigate on how the size of the vessel's wall thickness affects thermal conduction.
Be able to infer an order relation between the vessel's wall thickness and thermal conduction.

Recommended setting and pedagogical approach

4.1. Pupils collaborate in groups of two.

4.2. Pupils collaborate in teams of two on each computer.

4.3. Pupils collaborate in teams of two on each computer.

Important questions

4.1. Recalling the initial problems examined with the house insulation, and in the light of what you have learned so far, how would you answer?
How is the problem of thermal insulation related to that of energy saving?
How do all addressed disciplinary contents related to the technical characteristics of the most commonly used glass panes?
How do all addressed disciplinary contents related to the technical characteristics of the most commonly used bricks?

4.2. Your mother left on the stove a little more the milk she was preparing for you. In order to cool it down quickly, she poured it from the initial glass into a larger one having the same wall thickness. She believed that this way the milk should cool down faster.
Do you agree or disagree with her? Why?
How does a vessel's surface area affect heat transfer?
Which is the order relation between the surface area of a vessel, and the time elapsed in order to cool down a liquid within it?

4.3. Your mother left on the stove a little more the milk she was preparing for you. In order to cool it down quickly, she poured it from the initial glass into another one with thicker wall. She believed that this way the milk should cool down faster.
Do you agree or disagree with her? Why?
How does a vessel's wall thickness affect heat transfer?
Which is the order relation between a vessel's wall thickness and the time elapsed in order to cool down a liquid within it?

Material resources

4.1. Power point slides.

4.2. Virtual Experiments on the computer: simulated experiments: Cooling Lab 6

4.3. Virtual Experiments on the computer: simulated experiments: Cooling Lab 6

Hints and Tips
Refer to Teacher's Guide - Unit 4

TEACHER'S NOTES - UNIT 1: THERMAL CONDUCTION IN EVERYDAY LIFE

1.1. HOUSE INSULATION

Duration: 1 hour

Hints and tips:

1.1.1. ACTIVITY: HEAT LOSSES

PUPIL ACTIVITIES	TEACHER'S COMMENTS
You are at home in Naples and you would like to have an inner temperature of about 20° C, but this is not always possible. Why? Identify the house's parts in which there could be heat losses from inside to outside.  FIGURE T1	This question allows a discussion about thermal insulation and thermal exchanges between environments at different temperature. This question refers explicitly to the solids used commonly in houses and attracts students' attention of their differences as regards thermal insulation. It could be useful, at this stage, to discuss about the feeling of warmness and coldness coming from touching different bodies, and also ask students about the above bodies' temperature.

1.1.2. ACTIVITY: MATERIALS FOR HOUSE INSULATION

PUPIL ACTIVITIES	TEACHER'S COMMENTS
Which materials would you use for the walls? For the windows? For the doors? Explain Observe the snow on the rooftops of the two houses (circled in red). According to your opinion, which rooftop has a better thermal insulation? Explain  FIGURE T2	It is asked to observe how much snow has melted and to associate this result to thermal insulation.

1.2. CUPS FILLED WITH LIQUID

Duration: 1 hour

Hints and tips:
An every day situation

1.2.1. PREDICTION: “A DAY AT SCHOOL”

PUPIL ACTIVITIES	TEACHER'S COMMENTS
One day in school the pupils encounter the following problem: *“A cold winter day, you went with your friends to the school buffet and ordered hot chocolates to drink. The drinks had the same temperature and were served in different cups.* *Which cup of hot chocolate would you choose, in order to be able to hold it without getting burned?”* *The glass, Metal or the Plastic cup?* *Provide a short explanation of your choice.* *After a while, in which cup would the chocolate cool down easier?* *Provide a brief explanation describing your point of view.”*	The pupils in preceding lessons noticed that heat is transferred from hot water, contained in a vessel, to the environment. Thus, after a while, the hot water in the vessel will cool down. This question addresses pupils' views regarding the role of vessels in an every day context. The teacher carries out a discussion to prompt the pupils to think of this familiar every day problem situation. The pupils should well understand that what they are looking is the role played by the cups' material, rather than the water within. After individual prediction by each pupil the teacher coordinates a short discussion in order that the pupils reflect and announce their predictions to the class.

1.2.2. EXPERIMENT: MEASURING WATER TEMPERATURE DROP IN DIFFERENT MATERIALS' CUPS

PUPIL ACTIVITIES	TEACHER'S COMMENTS
The pupils should only provide a prediction about the water temperature, without any justification.	Initially, as pre-requisite, students should have performed similar experiments. They should be acquainted with temperature measurements in the laboratory. The pupils are given only the set of cups that they will experiment with and make prediction about this specific situation
The pupils decide how to organize the team (who will measure temperature, who will measure time, who will record data etc.).	The teacher has to prepare hot water before the start of the unit. Hot water should be above 80 °C so that during the usual initial time delays (providing instructions to pupils, etc.) its temperature does not fall under 70 °C. The teacher should take care that the temperature of water in the cups and the temperature in glass basins is the same. Temperature may vary from group to group, but NOT within a group. In case the teacher opts to use different size heating beakers than the ones suggested, he should take care the quantities of water used result into the same water levels in the inner heating beaker and the (outer) small glass basin. Each pupil should be aware of his role in the group and what he is expected to do in each phase of the experiment.
The pupils measure the temperature of the water poured in the 2 cups by the teacher. The pupils place each cup, along with its thermometer, in a small glass basin and then leave the quantities of hot water in the cups to interact with the colder water of the basin. The pupil operating the chronometer should announce time every 0.5 min (they should get familiar with its operation to not accidentally reset it). The pupils measure the temperature of the water in the cups every 0.5 min, fill in Table 1 and answer the questions of the worksheet.	The teacher should remind the pupils that: they should keep the two thermometers immersed in the water at the same depth, taking care they don't touch the walls of the cups and that they are not accidentally displaced by the pupils. The pupils should be constantly monitoring the thermometer and be ready to announce temperature readings when asked. The teacher acts as facilitator and assists in experimentation. The pupils are expected to observe an initial rapid fall of the temperature in the two cups. Temperature values will converge fast in the beginning and then, at a slower rate, all water temperatures will gradually approach room temperature. When the first such convergence becomes obvious, the teacher should ask the pupils to stop data collection

PUPIL ACTIVITIES	TEACHER'S COMMENTS
Each group announces their results to the class. Whole classroom discussion	The teacher collects and organizes pupils' results in the appropriate table (see APPENDIX I: Table). It is suggested that he also prints the blank table on a transparency, as well as the results page, to be able to fill in the results directly on the overhead.

1.2.3. ACTIVITY: CLASSIFICATION OF CUPS' MATERIALS

PUPIL ACTIVITIES	TEACHER'S COMMENTS
Pupils compare the result of the experiment to their experimental predictions and proceed to identify and justify any differences. Pupils discuss the group results and compare the materials regarding their thermal conductivity.	The teacher coordinates the discussion and helps pupils to draw conclusions regarding the thermal conductivity of the three materials. He also identifies and discusses any possible differences in experimental data between the teams. If the teacher finds it useful, he may print and complete the results page (see APPENDIX II: Conclusions) on the overhead during the discussion and the drawing of conclusions by the pupils.

1.2.4. ACTIVITY: "A DAY AT SCHOOL" REVISITED

PUPIL ACTIVITIES	TEACHER'S COMMENTS
The pupils reflect on their predictions taking into account experimental evidence.	The teacher makes links between the experiments and the everyday situation, discusses the methodology and prompts the pupils to accept or reject their predictions on the basis of experimental evidence.

APPENDIX I

	1st group		2nd group		3rd group	
Time	Glass	Plastic	Glass	Metal	Plastic	Metal
Initial						
0.5 min						
1 min						
1.5 min						
2 min						
2.5 min						
3 min						
3.5 min						
4 min						
4.5 min						
5 min						
5.5 min						
6 min						
6.5 min						
7 min						
7.5 min						
8 min						
8.5 min						
9 min						
9.5 min						
10 min						

TABLE 1

Appendix II (Transparency by the teacher)

CONCLUSIONS

GROUP 1

- The water in the .... cup **cools down faster** than the water in the .... cup.
- Therefore, ... conducts heat easier than ....

GROUP 2

- The water in the .... cup **cools down faster** than the water in the .... cup.
- Therefore, ... conducts heat easier than ....

GROUP 3

- The water in the .... cup **cools down faster** than the water in the .... cup.
- Therefore, ... conducts heat easier than ....

RANKING OF MATERIALS ACCORDING TO THEIR THERMAL CONDUCTIVITY

MOST THERMALLY CONDUCTIVE: ....

INTERMEDIATELY CONDUCTIVE: ....

LEAST THERMALLY CONDUCTIVE: ....
OR MOST INSULATING

TEACHER'S NOTES - UNIT 2: MICROSCOPIC MODELS FOR THERMAL PHENOMENA

As an introduction to this Unit the teacher should explain that the materials can be categorized according to their thermal behavior in broad categories

Ceramics include glass, porcelain .. and **Polymers** include all kind of plastics… and **Metals** include iron, steel, aluminium, copper

At the microscopic level it is actually impossible to see, even with the more powerful optical microscope, the particles of materials and their arrangement, and so we will use a computer simulation in order to understand how scientists imagine them.

Ceramics materials are divided into crystalline and amorphous.

In crystalline materials, the positions of their particles form a geometric pattern or *lattice*, in which all the particles are arranged into equidistant rows and columns. In amorphous materials, the particles also form a lattice, but their positions are random.

Metals
At the microscopic level, such materials are described as a lattice of particles, with electrons that are more or less free to wander around the material's lattice.

2.1. TEMPERATURE AND THE MICROWORLD

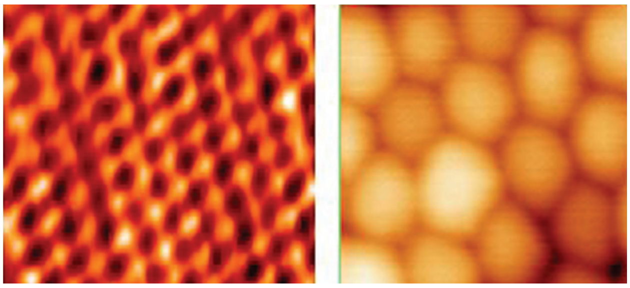
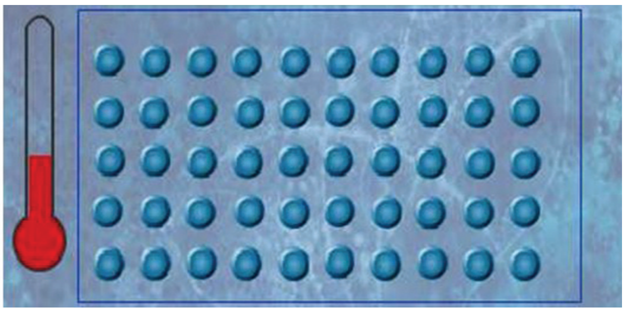
Duration: 1 hour

Hints and tips:

PUPILS' VIEWS

PUPIL ACTIVITIES	TEACHER'S COMMENTS
The pupils express their point of view on the following question: *"In the previous lab, we observed that the temperature of hot water in the metal cup was falling sooner than in the plastic one. Thus, we conclude that metals conduct heat better than plastic.* *Why is it so? What do you think happens?"*	The pupils in the previous unit experienced that the temperature of hot water in the metal cup falls down faster than in the plastic cup. This task aims at recalling, on behalf of students, the experimental outcomes of the previous unit and also to start to relate the microscopic behavior with a microscopic model. Through this question, the teacher can investigate whether the students have an idea of the micro world or of the elementary constituents of matter.

2.1.1. COMPUTER ACTIVITY: CERAMICS

PUPIL ACTIVITIES	TEACHER'S COMMENTS
The pupils discuss about the teacher's explanation of the structure of different materials Model observation The pupils observe the two images of the WS; they focus on the small differences between ceramics and metals. And also between crystalline and amorphous ceramics. Guided observations by the pupils. The pupils observe the model of the inner structure of ceramics.	The teacher addresses the fact that the image is a representation and that the real dimensions are much smaller; it could be useful, at this stage, to show pictures (models) of microscopic structures e.g. obtained with a scanning tunneling microscope, as the following ones.  FIGURE T3 The teacher makes examples of common objects that are ceramics or metals. Initially, when pupils observe the first simulation, the teacher should clarify the meaning of a "simulation". He should emphasize that it is a representation of the structure of these materials. The real dimensions of the depicted objects are around 10^{-6} m The teacher should avoid mis-conceptions that could be induced by such representations, and thus, during the activity, make many references to reality and address the limits of the model. The teacher prompts the pupils to carefully study and discuss the WS, to identify the differences of crystalline from amorphous materials and to write down their observations in the figure captions.
The pupils run simulation "Microscopic", then run "Lab1" and choose "Step A1".  FIGURE T4 They observe the particle vibrating in a crystalline ceramic material at a low temperature. Pupils raise the temperature and observe what happens at higher temperatures.	The teacher facilitates the pupils to arrive to the following conclusion: the more the temperature of a crystalline ceramic rises, the more the particles of the material vibrate. The teacher should take special care to assist the pupils in observing the way the particles vibrate, and compare the vibrations in different columns of the model. Finally, the teacher coordinates the discussion

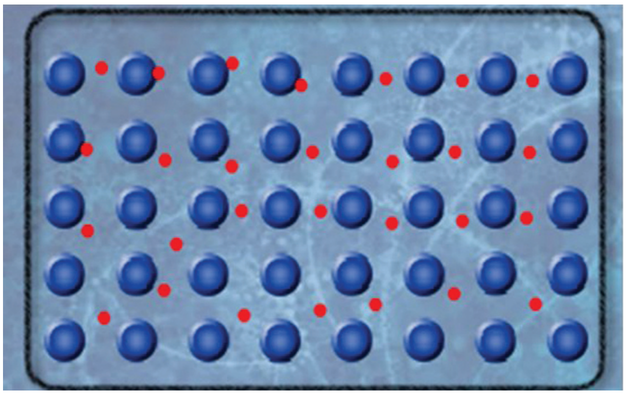
2.1.2. ACTIVITY: WHAT WOULD HAPPEN IF…

PUPIL ACTIVITIES	TEACHER'S COMMENTS
The pupils draw the conclusion that temperature it is not possible to go below a certain temperature value called the "absolute zero"	This content is not treated in usually taught.

2.1.3. ACTIVITY: TEMPERATURE AND PARTICLES' MOTION

PUPIL ACTIVITIES	TEACHER'S COMMENTS
The pupils draw the conclusion that temperature relates to particles' movement	If the students are familiar with the concept of kinetic energy, then the temperature should be linked to this type of energy.

2.1.4. COMPUTER ACTIVITY: METALS

PUPIL ACTIVITIES	TEACHER'S COMMENTS
The pupils, still in the same simulation, choose "Step A1". They read and discuss with the teacher the short text about free electrons and relate, when possible, this knowledge to what they have been taught in other courses Model observation The pupils observe the internal structure of metals, focus their attention on the motion of the free electrons and answer to the questions of the WS.	The simulation of the structure of metals aims to facilitate the pupils to focus on the role of the free electrons. The following should clarify that:  FIGURE T5 The red balls represent the free electrons; the color allows distinguishing them from the lattice particles. All dimensions (relative and absolute) are not real. The teacher should point out and emphasize the above assumptions, in order to prevent the creation or reinforcement of misconceptions, not only before using the simulations, but whenever necessary

2.1.5. ACTIVITY: TEMPERATURE AND PARTICLES' MOTION

PUPIL ACTIVITIES	TEACHER'S COMMENTS
Model exploration The pupils relate the continuous motion of electrons to the heat transferred macroscopically to the metal. Guided observations by the pupils	The teacher focuses pupils' attention and asks them to observe and comment on: the lattice particles' vibrations before and after the temperature rise; the motion of electrons, and their "collisions" with the lattice particles; The motion of the electrons at the 1st column compared to the motion of the electron in the last column. Pupils comment on the simulation and complete their WS, answering to the questions posed. The teacher helps pupils to express their answers using the appropriate scientific terms.

PUPIL ACTIVITIES	TEACHER'S COMMENTS
Finally, pupils compare the results from the two simulation runs and draw conclusions. They write their views, thus providing valuable feedback to the teacher.	The teacher discusses and points out the differences in the thermal conduction in ceramics and in metals.

2.2. THERMAL CONDUCTION AND THE MICRO WORLD

Duration: 1 teaching hour

Hints and tips:

2.2.1. EXPERIMENT: TWO BARS HEATED AT ONE END

PUPIL ACTIVITIES	TEACHER'S COMMENTS
Prediction Observe your teacher as he performs the experiment. He warms up, with two small candles, two bars; a metal bar and a glass bar. On top of both rods, and at the same distance from the end that is heated up, there are four small blobs of wax, placed at equal distances. The wax, when heated up, will start melting *In which rod will the wax melt first?* *Justify your answer.* The students, make individual predictions before performing the experiment and discuss with the teacher The pupils participate in the whole classroom discussion The pupils compare their predictions with the experimental results.	The teacher describes the demonstration experiment and fosters students' predictions The bars should be about 10 cm long. It is better to place on both bars more than one blob of wax and to have the first one right beneath the warmed up end of each bar. The teacher carries out the experiment; discusses with pupils their and prompts the pupils to think whether this activity could be related to an everyday experience. Approximately 5-7 minutes later all the wax blobs on the metal rod will have melted. But the first blob to melt will be that on the glass rod near the candle, since the glass warm up locally but then it transfers heat at a lower rate than in the metal. If one asks students explanation about this phenomenon, answers as "heat is blocked within the glass" may come out. In order to avoid such mis-conception it is important to let the experiment continue well after all the wax blobs on the metal have melted. After about 30 min all the wax will have melted also in the glass bar. This result can focus students' attention on the different time involved.

2.2.2. COMPUTER ACTIVITY: THE MICROSCOPIC MODEL OF TEMPERATURE INCREASE IN TWO BARS

PUPIL ACTIVITIES	TEACHER'S COMMENTS
Run simulation "Microscopic Model" and then "Lab4". Press "Step B" to start and select "Graph" Press "play" and observe how the various parts of the two rods gradually get hotter. Observe the thermometers that indicate the temperature at various positions on the rod. The pupils observe, in the same representation, both macro and micro. Students observe the simulation and report on the WS. Special care has to taken in observing the movement of the lattice particles in the first and last row.	Initially again the teacher should clarify the meaning of a "simulation[2]" which is a representation of the experiment. He also clarifies that on the upper part of the screen is depicted the macroscopic phenomenon of heating up of a bar; the red cylinders represent thermometers and the ordinate axis is the bar's temperature. Reference to the experiment is important, in order to link the visualization with what they observed. The lower part depicts the microscopic representation. It is important to address the dimensions issue in order to avoid mis-conceptions. The students should observe that conduction is faster in the metal bar, by focusing on the time icon.

EXAMPLE

	Ceramic Material	Metal
Time needed for heat transfer from the left end of the rod to the right end	41 sec	7 sec
Final temperature at the left end of the rod	185 ˚C	100˚C
Final temperature at the right end of the rod	195 ˚C	160˚C
Temperature difference between the two ends of the rod	85 ˚C	35˚C
I conclude that the material is:	insulating	conductive

2.2.3. ACTIVITY: HEAT CONDUCTION IN CERAMICS AND IN METALS

PUPIL ACTIVITIES	TEACHER'S COMMENTS
The pupils compare the results of the Table The pupils are asked to reflect and write down how simulations helped them to understand the subject matter, i.e. the role simulations played in their learning of the new knowledge. At the end, the pupils are asked to draw conclusions on the process of thermal conduction in ceramic and metals.	Afterwards, the teacher prompts the pupils to make some links between simulated results and the demonstration experiment Important details to be discussed: The role of the environment. Also the air around the bar warms up. It is important that the teacher investigates on students' ideas about how heat propagates. It could be useful to propose, for such aim, a mechanical analogy of a system of suspended masses connected through springs, in order to understand hoe energy can be transferred from one place to the other The teacher guides students to conclusions

2. *NOTE: The simulations and the related assumptions are presented analytically in the description of the resources.*

TEACHER'S NOTES - UNIT 3: FROM MATERIALS TO CATEGORIES OF MATERIALS

3.1. THERMAL CONDUCTION IN METALS

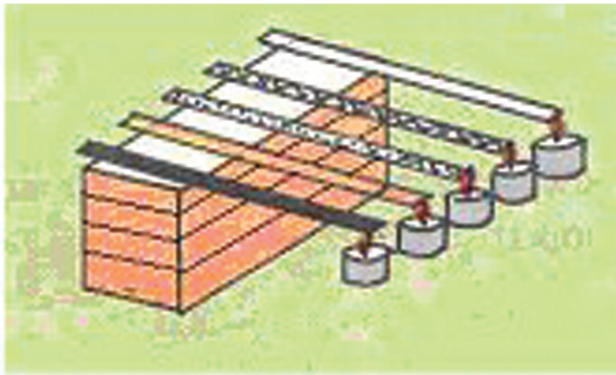
Duration: 2 teaching hours

Hints and tips:

3.1.1. ACTIVITY: EXPERIMENT WITH THE BARS AND WAX REVISITED

PUPIL ACTIVITIES	TEACHER'S COMMENTS
Recalling the former experiment with the bars and wax blobs The pupils discuss about the experimental technique. The pupils link experimental results with personal experiences for feeling thermal conduction. Preparation of the experiment in groups Having experienced the demonstration and the ensuing discussion the pupils are involved in group discussion about planning the following investigation.	The teacher prompts the pupils to discuss what happened to the wax and why and think of an interpretation in terms of thermal conduction. The discussion should also focus on the experimental technique e.g. why the wax is necessary? What evidence does it provide? Links with everyday phenomena where heat conduction can be observed are encouraged, such as a spoon inserted in hot water. The teacher asks the pupils to work in teams to plan and suggest an experimental procedure in order to rank 5 metallic rods according to their thermal conductivity. He clarifies than inox and bronze are alloys. The teacher hands out a piece of thermal paper to each group. Only one side (that leaves a visible mark when scratched) with a fingernail of the thermal paper is thermo chromic.

3.1.2. EXPERIMENT: RANK 5 METALLIC MATERIALS ACCORDING TO THEIR THERMAL CONDUCTIVITY

PUPIL ACTIVITIES	TEACHER'S COMMENTS
The pupils first have to identify the rods, by using the hints contained in the table of the WS regarding their properties. The pupils place the thermal paper on the book and they place the 5 rods parallel to each other. Then they have to stabilize the rods by using erasers or pencil sharpeners. The rods should protrude beyond the book by about 3 cm .	 FIGURE T6
The pupils make a tag on the thermal paper marking the position and the material of each rod. Then they place under the free end of each rod a candle WITHOUT lighting it up. The pupils position the candles under each rod SIMULTANEOUSLY, and take special care that the ends of all rods are WELL IN CONTACT with the flames of the respective candle. Pupils quench the candles when asked by the teacher. **WARNING: Pupils should NOT touch the rods using bare hands, especially the heated end!** The pupils observe the traces left on the thermal paper and record their observations on the WS. The pupils measure and compare the length of the traces and then fill up the table	The teacher hands each group 5 candles. The candles should be the same, so when lit, their flames touch the rods in a similar manner. Then, the teacher lights up the candles and asks pupils to position them under each rod SIMULTANEOUSLY. The candles should be burning for about 10 minutes. After about 10 min, the teacher removes the rods from the thermal paper, using heat resistant gloves. The teacher asks the pupils to compare the traces left by the metallic rods and rank them in increasing length order: The longest trace is left by the copper rod, then aluminium rod, bronze, iron and finally the very small trace left by the inox rod. **(We note here the thermal conductivity coefficients (k, in W/m*K):** Copper: 398 Aluminium: 247 Bronze: 120 (70% Cu/30% Zn) Iron: 80 Inox: 15.9 (Grade 316))

3.1.3. ACTIVITY: HEAT CONDUCTION AND THE MICROSCOPIC INTERPRETATION

PUPIL ACTIVITIES	TEACHER'S COMMENTS
The pupils work in groups to decide **which metallic rod is more conductive** on the basis of experimental evidence	The teacher reminds the pupils that bronze and inox are alloys that are neither better nor worse conductors than pure metals.
The pupils are helped by the teacher to draw on the features of the microscopic model and in particular the role of free electrons in metals	The teacher discusses with the class that the conductivity in metals or alloys depends on the metal's material or on the composition of the alloy.
Additionally a discussion on whether we use conductive objects and materials at the house or elsewhere.	Prompted by the last question of the WS regarding the interpretation of the phenomenon, the discussion in the classroom may lead to the conclusion that thermal conduction in metals depends on the **Number** of the free electrons.  FIGURE T7

3.2. THERMAL CONDUCTION IN CERAMICS, PLASTICS, TEXTILES

Duration: 1 hour

Hints and tips:

PUPIL ACTIVITIES	TEACHER'S COMMENTS
The pupils express what they have understood about the first experiment about thermal conductivity of different materials	The teacher prompts the students to recall the first experiment and interpret it on the basis of all that has been addressed up to now.

3.2.1. COMPUTER ACTIVITY: COOLING WATER IN DIFFERENT CERAMIC MATERIALS' CUPS

PUPIL ACTIVITIES	TEACHER'S COMMENTS
It is possible to ask, at first, for a prediction of the T(t) curve. The pupils run the virtual lab "Simulated Experiment", choose "Cooling" and then "Lab3". The pupils compare the cooling of two equal volume quantities of water (50 ml) having equal temperatures (80^{o} C) but contained in two different vessels, a glass one and a Perspex one.	The pupils often predict that, for both cases the graphs will converge towards 50 ^{o}C, which is the mean value of the initial temperatures of the equal quantities of water. The teacher underlines the potentialities of the virtual experiment, which allows for rapid variations of the parameters. The time evolution of the water cooling is the focus of this activity. The T(t) curve has to be carefully observed and the fact that this is an approach to equilibrium phenomenon has to be addressed.
The pupils observe all details of the simulation and collaborate within the teams. The pupils observe the thermometer and the related real time graph. The pupils are asked to compare the two graphs and to focus on the time required to reach thermal equilibrium.	While the pupils carry out the and while the phenomenon is evolving, they observe that: - hot water in the vessel is cooling down, by observing the thermometer reading, on the right hand side of the simulation, and to connect the latter to the T(t) curve appearance. It is common that pupils refer to the T(t) curve as a "linear" decay. - the symbol for heat 'Q' represents the net heat flux on a small surface of the container. It fades out as the water cools down and disappears when thermal equilibrium is reached.

3.2.2. ACTIVITY: CLASSIFICATION OF CERAMICS' THERMAL CONDUCTIVITY

PUPIL ACTIVITIES	TEACHER'S COMMENTS
The pupils repeat the same procedure also for the Lab 4 and 5 simulations. And fill in Table 1.	The teacher addresses the final temperatures and the time elapsed and lets pupils draw their conclusions about thermal conductivity of different insulating materials.

3.2.3. ACTIVITY: PLASTICS AND THEIR USE

PUPIL ACTIVITIES	TEACHER'S COMMENTS
Pupils are asked to describe how and in what cases they use plastics	The teacher addresses the issue of the use of different kinds of plastics in every day life.

3.2.4. ACTIVITY: USING DIFFERENT TEXTILES FOR THERMAL INSULATION

PUPIL ACTIVITIES	TEACHER'S COMMENTS
Pupils can focus on different materials textiles used in every-day life	The teacher can go back to some of the contents addressed in the pre-test and make pupils reflect about different insulating textiles. The role of air inclusions within the textiles is discussed as a general issue regarding thermal insulation

At the end of these activities the teacher introduces the terms: conductors and insulators

TEACHER'S NOTES - UNIT 4: FACTORS AFFECTING THERMAL CONDUCTION

Duration: 1 hour

Hints and tips:

As a first step the teacher should recall the initial Scenario and discuss the students' answers to the worksheet in the light of what they have learned so far.

4.1. MATERIALS' CONDUCTIVITY

4.1.1. ACTIVITY: READING THERMAL PHOTOGRAPHY

PUPIL ACTIVITIES	TEACHER'S COMMENTS
Students are asked to observe the image and focus on the colors code, in order to identify what part of the house is more or less insulated.	The teacher explains the basic of thermal photography and the codes used for the colors. It may be useful to show different pictures.

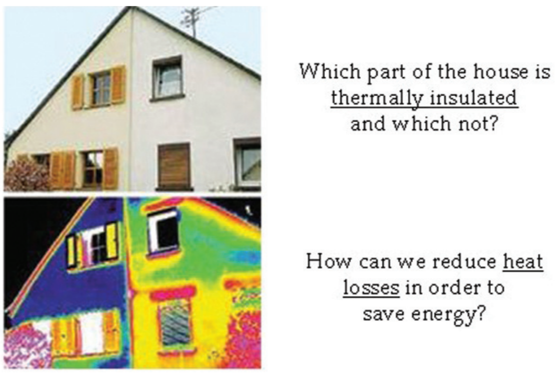


FIGURE T8

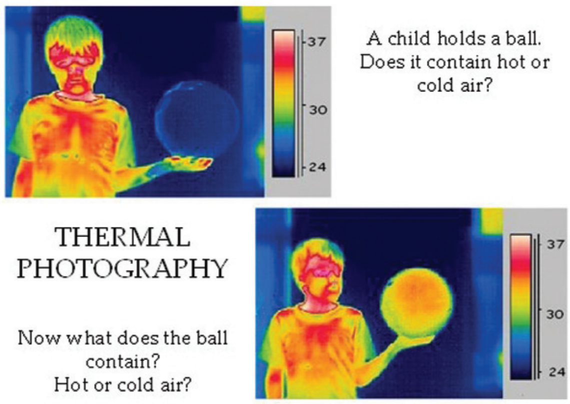


FIGURE T9

4.1.2. ACTIVITY: CHOOSING APPROPRIATE MATERIALS FOR THE WINDOWS

PUPIL ACTIVITIES	TEACHER'S COMMENTS
Pupils are asked to relate the disciplinary contents they learned and the technical characteristics on the most commonly used glass panes.	The teacher addresses the issue of the links between the technical characteristics and of the role of the air, as regards thermal insulation of glass panes.

Table

Type of glass	K (W/m^2K)
single 4mm	5.8
single 6mm	5.7
single 10mm	5.6
single 12mm	5.5
double 4-12-4	2.9
double 6-12-6	2.8
double 10-12-6	2.7
double 12-12-6	2.6

FIGURE T10

4.1.3. ACTIVITY: CHOOSING APPROPRIATE BRICKS

PUPIL ACTIVITIES	TEACHER'S COMMENTS
Pupils are asked to relate the disciplinary contents they learned and the technical characteristics on the most commonly used bricks.	The teacher addresses the issue of the difference in terms of thermal insulation of different types of bricks.

Thickness of outer wall	K-value with additional thermal insulation (in W/m².K)					
Additional insulation	Not insulated	6 cm	8 cm	10 cm	12 cm	14 cm
38 cm of plain brick	1.45	0.45	0.37	0.31	0.27	0.24
38 cm of cored brick	0.36	0.23	0.21	0.19	0.17	0.16

Plain brick

Cored brick

Brick wall with insulation

FIGURE T11

4.2. SURFACE AREA

Duration: 1 hour

Hints and tips:

4.2.1. PREDICTION: ONE DAY IN THE HOUSE

PUPIL ACTIVITIES	TEACHER'S COMMENTS
Your mother left on the stove a little more the milk she was preparing for you. In order to cool it down quickly, she poured it from the initial glass into a larger one having the same wall thickness. She believed that this way the milk should cool down faster. *Do you agree or disagree with her? Why?* After students' prediction a class discussion is encouraged.	The teacher refers to the first question asked in the module about an everyday life situation and prompts the students to reflect on the role of a vessel's base surface as regards thermal conduction. The teacher invites the students to share their predictions and write on the blackboard the most significant ones.

4.2.2. COMPUTER ACTIVITY: VESSELS OF DIFFERENT SURFACE AREA

PUPIL ACTIVITIES	TEACHER'S COMMENTS
The pupils run "Simulated Experiments", choose "Cooling" and then "Lab6". The pupils, in this simulated experiment, cool down 50 ml of water at 80 °C in a vessel containing equal quantity of water (50 ml) but having a temperature of 20 °C. You may choose a small or large surface area for the base of the vessel containing the hot water.	The virtual experiment refers to cooling. The experimental procedure is familiar to the pupils from previous units and should not have any difficulty. This activity could be a first assessment of students' capabilities in handling a virtual experiment The teacher can invite the pupils to repeat many time the experiment in order to carefully observe all simulation elements.

4.2.6. ACTIVITY: INFLUENCE OF SURFACE AREA ON COOLING TIME INTERVAL
4.2.7. ACTIVITY: "ONE DAY IN THE HOUSE" REVISITED

PUPIL ACTIVITIES	TEACHER'S COMMENTS
The pupils infer an order relation between the vessel's base surface and thermal conduction On the basis of the experimental evidences the students go back to the initial problem and compare their prediction with the experimental results.	The teacher coordinates class discussion so that the pupils: - conclude that a vessel's surface area affects the process of heat transfer - the larger the surface area of a vessel, smaller the time elapsed in order to cool down the liquid The teacher, invites the students to reflect on the problem posed at the beginning. It is important, at this stage, that the students use scientific terms.

Resuming

Note: One may add to Worksheets 7 and 8 an activity about a Virtual Heating Experiment with constant power. In this presentation they are proposed as Assessment activities. The notes below refer to both Worksheets 7 and 8.

PUPIL ACTIVITIES	TEACHER'S COMMENTS
Assessment task The pupils, after the cooling experiment, can go to a heating virtual experiment at constant power. They run "Simulated Experiments", choose "Heating" and then "Lab3". The pupils, in this virtual experiment, will heat up 100 ml of water at a temperature of 20 °C on a heater providing a constant heat flow.	The teacher lets the students work on this activity in order to tests if they have acquired some of the learning objectives as: the use of the virtual laboratory, the comprehension of the addressed contents. The teachers guides the students to understanding that thermal conduction is influenced by a vessel's surface area both in cooling and in heating, in the same way.

4.3. THICKNESS

Duration: 1 hour

Hints and tips:

4.3.1. PREDICTION: ONE DAY IN THE HOUSE

PUPIL ACTIVITIES	TEACHER'S COMMENTS
Your mother left on the stove a little more the milk she was preparing for you. In order to cool it down quickly, she poured it from the initial glass into another one with thicker wall. She believed that this way the milk should cool down faster. *Do you agree or disagree with her? Why?* After students' prediction a class discussion is encouraged.	The teacher refers to the first question asked in the module about an everyday life situation and prompts the students to reflect on the role of a vessel's wall thickness as regards thermal conduction. The teacher invites the students to share their predictions and write on the blackboard the most significant ones.

4.3.2. COMPUTER ACTIVITY: VESSELS OF DIFFERENT THICKNESS

PUPIL ACTIVITIES	TEACHER'S COMMENTS
The pupils run "Simulated Experiments", choose "Cooling" and then "Lab1". The pupils, in this simulated experiment, cool down 50 ml of water at 80 ^{o}C in a vessel containing equal quantity of water (50 ml) but having a temperature of 20 ^{o}C. They may choose either 2.5 mm or 5 mm thickness.	The virtual experiment refers to cooling. The experimental procedure is familiar to the pupils from previous units and should not have any difficulty. This activity could be a first assessment of students' capabilities in handling a virtual experiment. The teacher can invite the pupils to repeat many time the experiment in order to carefully observe all simulation elements.

4.3.6. ACTIVITY: INFLUENCE OF WALL THICKNESS ON COOLING TIME INTERVAL
4.3.7. ACTIVITY: "ONE DAY IN THE HOUSE" REVISITED

PUPIL ACTIVITIES	TEACHER COMMENTS
The pupils infer an order relation between the vessel's wall thickness and thermal conduction. On the basis of the experimental evidences the students go back to the initial problem and compare their prediction with the experimental results.	The teacher coordinates class discussion so that the pupils: - conclude that a vessel's wall thickness affects the process of heat transfer - the larger the wall thickness of a vessel, larger the time elapsed in order to cool down the liquid The teacher, invites the students to reflect on the problem posed at the beginning. It is important, at this stage, that the students use scientific terms.

B: EVALUATION TASKS

B: EVALUATION TASKS

In this Section we describe the assessment tasks that can be submitted to students individually. In Par. 1 we describe the Pre and Post Questionnaires; in Par. 2 we describe a template for an interview to be submitted after instruction. The text of the Questionnaires, the relatives rubrics and the Interview Protocol are also reported.

1. THE PRE AND POST INSTRUCTION QUESTIONNAIRES DESCRIPTION

The *pre questionnaire* consists of six questions concerning both the pre-requisites (e.g. about heat and temperature) and the module contents (thermal conductivity of materials). Hereafter a brief description of the questions.

The first question is a standard one for investigating on students' ideas about the equilibrium temperature of bodies left for enough time in the same environment. There are both unanimated and animated bodies; while the latter have their own temperature, the former ones reach the same temperature as the surrounding medium.

The second question aims at focusing students' attention on the issue of thermal conductivity, by letting them choose, in a real life situation, between three cups where hot chocolate has been served.
Question three aims at addressing the issue that a perfect thermal insulator does not exist, again, exposing the pupils to a real life situation concerning the home heater.

Question four is also a standard one that lets students reflect on the fact that a piece of wood and a metal, that are in the same room, feel differently, as far as their temperature is concerned. The question aims at clarifying that the perception is linked to the different thermal conductivity of the bodies at hand. And that, in particular a metal is a better thermal conductor than wood.

In question five students are asked to figure out the most efficient way to keep a body (a snowman) at a constant temperature. The aim of such question is to have students understand that in order to maintain a bodies' temperature constant, one can use some special insulator as the snow jacket.

La last question focuses students' attention on the fact that a wooden spoon is more suitable to stir the hot soup, rather than a metal spoon. With this question one may address the issue of how heat is conducted from the spoon to the fingers and also in general how heat is transferred in the materials.

The Post questionnaire comprises the above six questions plus five extra ones.

In particular questions 6 and 10 aim at investigating students' understanding about the microscopic model addressed via the simulations.

Questions 7 and 8 focus on students' understanding of the difference between a conductor and an insulator; while question 9 aims at investigating one of the modules' general pedagogical aims about students' capacity to plan an experiment, by selecting appropriate setting and variables to be investigated.

Question 11, as question 9, probes the students' capacity to plan an experiment, in a virtual environment, in the case of a heating process.

2. INTERVIEW DESCRIPTION

A semi structured interview has been designed to be submitted after instruction.

The aim of the interview is twofold:

- to gather students' opinion about the performed activities from the point of view of their interest/motivation.
- to investigate the reasons for some specific answers given to the Post instruction questionnaire about relevant physics contents addressed in the Module.

PRE - QUESTIONNAIRE

1. During winter you are in a house in the mountains. The temperature inside the house is 6o C. There are different bodies in the house. Which is the temperature of each body?
   a. A woolen sweater
   b. A metal saucepan
   c. A wooden table
   d. A cat

   Explain

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2. In a cold winter day, you and two of your friends went to the school café to drink hot chocolate. The hot chocolate was served in cups made of three different materials plastic, metal and glass. All the drinks had the same temperature the time they were served to you. If you were to pick up a cup first, which of the three cups-glass, metal or plastic-would you choose in order to make sure that your fingers wouldn't be burned?
   Give a brief explanation of your choice:

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   In which of the cups you believe that the chocolate will cool down faster?
   Give a brief explanation

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3. You might have noticed that an electric water heater has a little red light which, when lighted, indicates that the heater is using up electricity. When the water reaches the desired temperature the light goes off. Of course the water heater is a well insulated apparatus, but…you will have seen that the little light, every so often, turns on even when the hot water is not used. Can you explain why does this happen?

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4. The top of a table is wooden and its legs are made of metal. When you touch the wooden top with one of your hands and one of the legs with the other, you will feel that the top is warmer than the leg. This happens because:
   a. Wood absorbs and stores heat while the metal doesn't
   b. Metal and wood have different temperatures
   c. The metal conducts heat faster than wood does
   d. Wood absorbs the cold
   e. The metal absorbs the cold

   Choose those answers that you think are correct and justify your choice.

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5. On a snowy day three friends made a snowman and showed it to another friend who come later. However, the sun had come out and the temperature had raised. Thus the friends had to decide how to keep the snowman from melting. Each of the friends expressed a different opinion.
   a) "Cover it, said one of them, with your ski jacket made of a composite material, fiberglass. This will keep it cold and will prevent it from melting"
   b) "No, said the other one, the ski jacket will warm it up and will make it melt, …cover it with aluminum foil"
   c) "However you cover it with will not make any difference"
   Who do you think was right? Justify your answer.

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6. A friend of yours uses a metal spoon to stir the food while cooking. After a while he feels his fingers burning. How do you think heat was transferred through the metal to the fingers of your friend?

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POST – QUESTIONNAIRE

1. During winter you are in a house in the mountains. The temperature inside the house is 6 °C. There are different bodies in the house. Which is the temperature of each body?
   a. A woolen sweater
   b. A metal saucepan
   c. A wooden table
   d. A cat

   Explain

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2. In a cold winter day, you and two of your friends went to the school café to drink hot chocolate. The hot chocolate was served in cups made of three different materials plastic, metal and glass. All the drinks had the same temperature the time they were served to you. If you were to pick up a cup first, which of the three cups-glass, metal or plastic-would you choose in order to make sure that your fingers wouldn't be burned?
   Give a brief explanation of your choice:

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In which of the cups you believe that the chocolate will cool down faster?
Give a brief explanation

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3. You might have noticed that an electric water heater has a little red light which, when lighted, indicates that the heater is using up electricity. When the water reaches the desired temperature the light goes off. Of course the water heater is a well insulated apparatus, but…you will have seen that the little light, every so often, turns on even when the hot water is not used. Can you explain why does this happen?

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4. The top of a table is wooden and its legs are made of metal. When you touch the wooden top with one of your hands and one of the legs with the other, you will feel that the top is warmer than the leg. This happens because:
   a. Wood absorbs and stores heat while the metal doesn't
   b. Metal and wood have different temperatures
   c. The metal conducts heat faster than wood does
   d. Wood absorbs the cold
   e. The metal absorbs the cold

   Choose those answers that you think are correct and justify your choice.

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5. On a snowy day three friends made a snowman and showed it to another friend who come later. However, the sun had come out and the temperature had risen. Thus the friends had to decide how to keep the snowman from melting. Each of the friends expressed a different opinion.
   a) "Cover it, said one of them, and with your ski jacket made of a composite material, fiberglass. This will keep it cold and will prevent it from melting"
   b) "No, said the other one, the ski jacket will warm it up and will make it melt, …cover it with aluminum foil"
   c) "However you cover it with will not make any difference"

   Who do you think was right? Justify your answer.

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6. A friend of yours uses a metal spoon to stir the food while cooking. After a while he feels his fingers burning. How do you think heat was transferred through the metal to the fingers of your friend?
Can you give a microscopic explanation to this phenomenon?

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7. **Complete the following sentences using the correct wording:**

Good heat conductors are the materials in which ....

Insulators are the materials in which ....

8. If you stir the hot food while cooking with a plastic spoon do you think you will feel your fingers burning?
Justify your answer.

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9. Kate has two cups, A and B. The cups are made of a different material but otherwise they are identical. Kate claims that the water in cup A warms faster than in cup B (same range). How can you find out which of her claim is right? Can you design an experiment?
Describe exactly what you are going to do and what equipment you will need.

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10. In the following two figures the microscopic structure of materials belonging to two different categories is shown, as seen through an imaginary microscope. Can you tell which of these materials conducts heat faster?
Justify your answer.

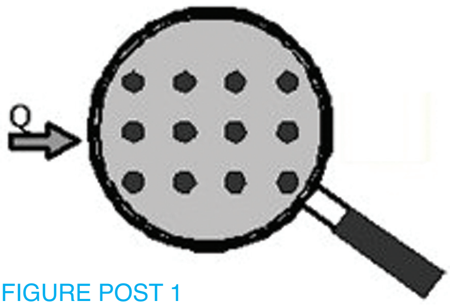

FIGURE POST 1

FIGURE POST 2

11. In the virtual laboratory environment, plan an experiment where you heat up an amount of water contained in different vessels. By this experiment you should infer what is the order relation between heat conduction and surface, or between heat conduction and thickness. Do you conclude that the same relations you found in the case of cooling down the water, hold also for the heating process?
Plan the experiment and explain.

RUBRICS

PRE - QUESTIONNAIRE

Question 1. Correct answer: All objects are at the house temperature. The cat has its own temperature.
Question 2. Correct answers: In order to make sure that the fingers wouldn't be burned the student should pick the plastic cup. The chocolate will cool down faster in the metal cup.
Question 3. Correct answer: The water heater is not perfectly insulated.
Question 4. Correct answer: The metal conducts heat faster than wood does.
Question 5. Correct answer: The ski-jacket will keep the snowman cold, for a sufficient amount of time, since it is made of a material which is a good insulator.
Question 6. Correct answer: Heat in metal is transferred through lattice vibrations and free electrons movements.

POST - QUESTIONNAIRE

Questions 1-6: Correct answer: the same of the pre-questionnaire.
Question 7: Correct answer: good heat conductors are the materials in which electrons participate to heat conduction; insulators are the materials in which heat conduction is due only to lattice vibrations.
Question 8: Correct answer: stirring the hot food with a plastic spoon allows the fingers not to get burned because plastic is an insulator.
Question 9: Possible correct answer: Put the same quantity of water (for instance 200 mg), at the same initial temperature (for instance 100 °C) in A and B cups, then with a thermometer in both the cups, covered with a polystyrene cover, measure the temperature at fixed instants of time.
Question 10: Correct answer: Figure B depicts a metal material since there are free electrons. Figure A depicts an insulating material.
Question 11: Correct answer: the only difference with the cooling process is the shape of the T(t) curve.

HOW TO EVALUATE

We refer to Document E of the original Greek module

Category 1: 'Scientific answer': Answers in this category are considered to be 'scientifically acceptable', i.e., the students correctly explain about the heat conduction and speak about microscopic mechanisms involved in the heat conduction.
Category 2: The correct answer has been chosen but the explanations are not backed by logic or understanding or contain scientifically invalid and logically incoherent information.
Category 3: The wrong answer has been chosen and the explanations are not backed by logic or understanding or contain scientifically invalid and logically incoherent information.
Category 4: No answer.
Category 5: The correct answer has been chosen without explanation.

Examples of answers are reported in the Italian version.

THE INTERVIEW PROTOCOL

1) What was the subject of the activities we performed? Which activity was most interesting for you?
2) What happens if you have a pan with a metal holder and you place it on the stove? What if the holder is made of wood?
3) *Observe the following images*

Which of the above images better represents the microscopic model in the metals?

FIGURE I-1

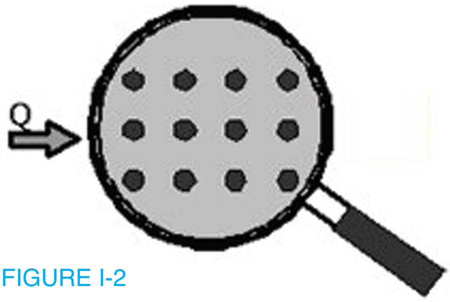

FIGURE I-2

4) *Observe the following picture*

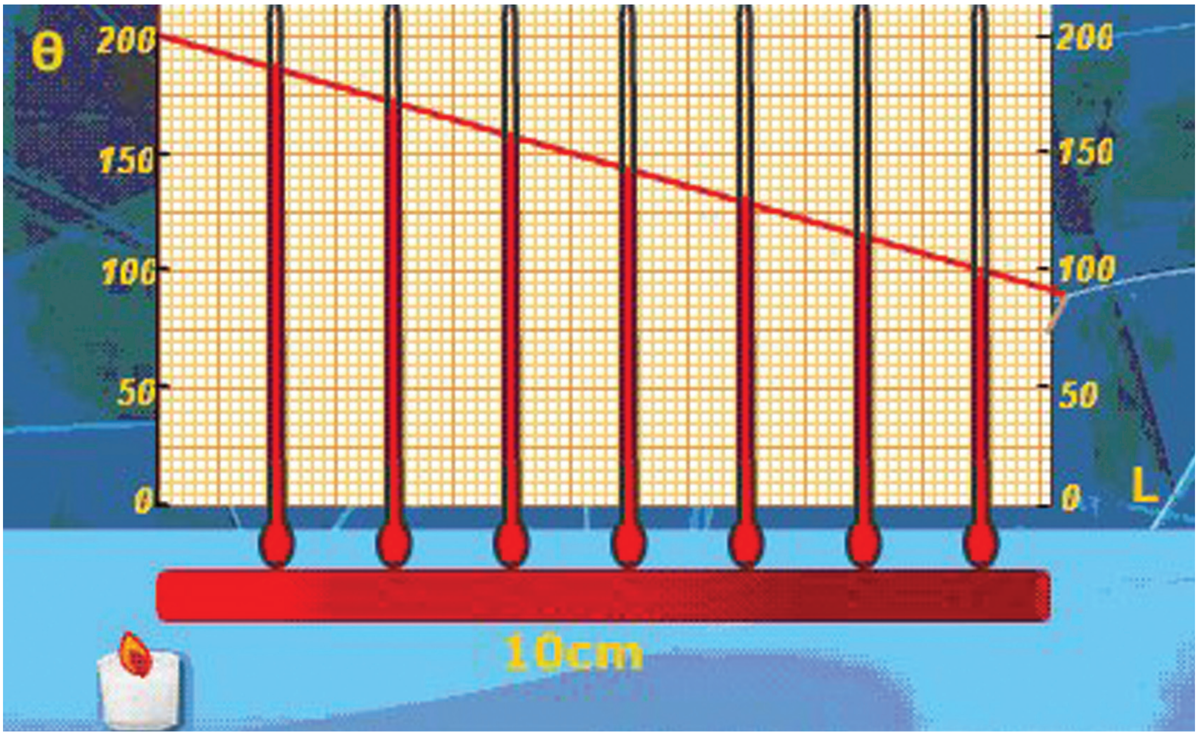

FIGURE I-3

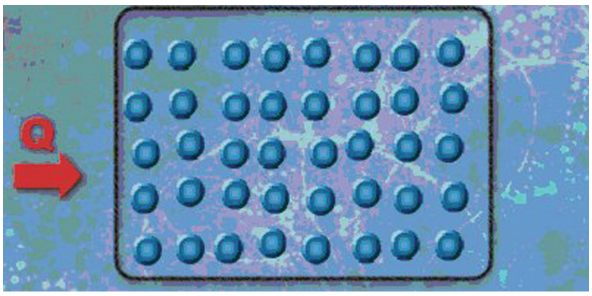

FIGURE I-4

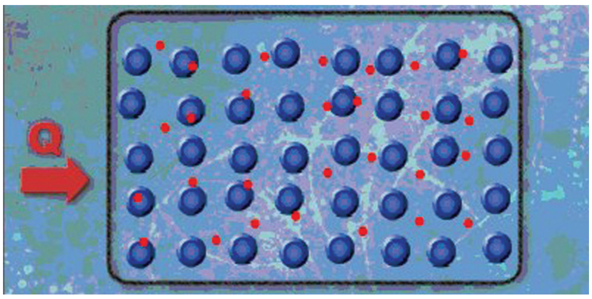

FIGURE I-5

Describe in brief the physical situation depicted and what interpretation was given of it during the activities.

5) Suppose you want to plan an experiment to observe heat transfer between two bodies; what would you do?

6) *Observe the following thermal photography of a house (on your right the code for the colors) Outside the temperature is about 40°C. In the house, due to air conditioning, the temperature is about 26°C.*

FIGURE I-6

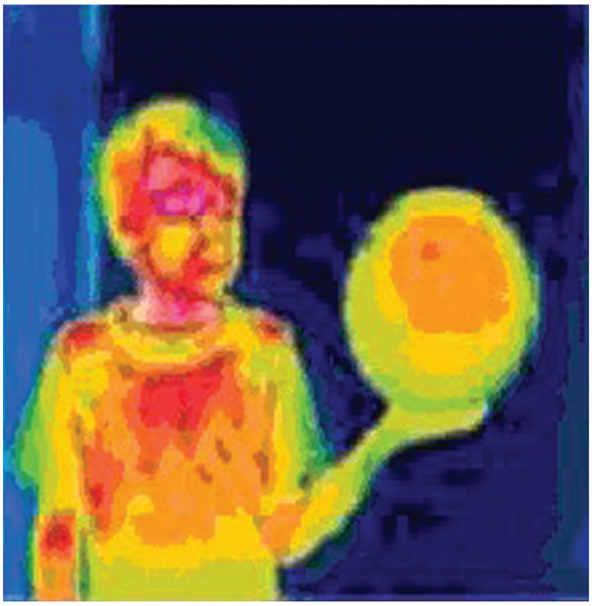

FIGURE I-7

What part of the house is insulated? The right hand side or the left hand side?

7) What would you do in order to prevent a snow man from melting? ?

MATERIALS
SCIENCE PROJECT

UNIVERSITY-SCHOOL PARTNERSHIPS
FOR THE DESIGN AND IMPLEMENTATION
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