



# Materials around us: Paper, metal and plastics

## Teacher guide



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## 1 Aims of the module

The main intent in this Materials Science module designed in Finland is to encourage students to learn the basics of the materials around us through classification, modelling (including the use of models), concept mapping, and Predict-Observe-Explain (POE) activities as well as through an industry site visit. Especially, the students should become familiar with properties and behaviour of common materials, their usage, microscopic models describing their properties and behaviour, and moreover, usage of (raw) materials in constructions and in manufacturing products.

<b>The Finnish Module</b>	
<b>Unit 1</b>	Classification activities, learning basics of plastics, metals and paper
<b>Unit 2</b>	POE-activities
<b>Unit 3</b>	Preparing interview questions for the articles, the site visit and writing the articles
<b>Unit 4</b>	Constructing concept maps and evaluation

Firstly, the students will learn in Unit 1 how materials can be classified based on their properties. These classifications serve also as the basis for the recognition of materials and learning the meaning of the concepts “paper”, “metal”, “plastics”, and “ceramics”. For example, the meaning for the concept “metal” is created through analysing artefacts which are made either of metal or non-metal (e.g., steel vs. plastics). The comparisons and classifications help students to recognise the properties of metal objects and constructions, and create meaning for the concept, metal. Through the classifications the students will learn about the everyday use of different materials and artefacts made of these materials.

The structure of matter is one of the most fundamental topics in science. A meaningful understanding of this topic is essential for developing a solid basis for further scientific studies. Therefore, secondly, the students will take a deep look at microscopic models, which describe structure, properties, and behaviour of matter, especially in the case of metals, paper, and plastics in Unit 1. Computer simulations and modelling will be used here and, moreover, the students will use models to explain the structure and behaviour of matter. The students are encouraged to use different types of models (e.g., building blocks, computer simulations, and theoretical representations) to illustrate the structure and behaviour of

matter. The meaning and the use of a model are discussed, including its advantages and limitations.

Thirdly, the models will be compared and analysed through science inquiry activities. Especially, the Predict-Observe-Explain (POE) strategy will be used in Unit 2. The use of POE requires students to integrate the macroscopic view with the microscopic view and an ability to provide a particulate and molecular explanation for the structure, properties and behaviour of materials. Therefore, the validity of models will be analysed from the point of view of the properties of materials, the use of materials in daily life, and the use of materials as raw materials in industry. Consequently, the understanding of the structure of matter includes the understanding of the nature of matter, microscopic and sub-microscopic models, as well as the relationships between the structure, properties, and applications of materials. Within science inquiry activities students will develop learning skills such as question-sorting, reading scientific texts, and presenting scientific knowledge, as well as inquiry skills such as asking questions, designing and conducting scientific experiments, and finally, they can even learn creative designing of artefacts.

Fourthly, an industry site visit will be organised in Unit 3 to endow students with the opportunities to learn in-depth about properties and use of materials. Before the visit, in Unit 1 the students will become familiar with the production of materials and processes in that production. During the visit, students will learn about the use of materials as raw materials in manufacturing and in production of artefacts. In addition, the students will become familiar with material science related careers in an industrial site. The site visit will continue the classification theme as well as analysis of properties and use of materials. Consequently, the module presents the topic, materials around us, not only as a body of scientific knowledge, but also the technological aspects are integrated and studied as a subject that influences students' lives and affects the society in which they live.

Finally, in order to help the students to form a holistic view of materials, their use and properties, concept mapping will be used in Unit 4. Concept maps will be created using the CmapTools software. Concept maps will be employed also in student evaluations.

## 1.1 Intended learning outcomes

In detail the students will

1. Understand the basics of science concepts, principles, and systems in the contexts of materials and their properties (appropriate to grade level):

- Students can identify basic materials and know the terminology used in describing them (All Units);
- Students understand the meaning of the basic materials science concepts and principles: a material has certain physical and chemical properties and materials are distinguished from each other based on their properties; materials are used for production of artefacts and materials are selected to the artefacts based on their properties (Units 1 and 2);
- Students understand basic microscopic models, which describe structure of matter, properties and behaviour of matter, especially in the case of metals, paper and plastics (Units 1 and 2);
- Students understand the ways of representing materials on different levels: macroscopic, microscopic, and sub-microscopic level as well as on the symbolic level, and can relate to and shift from one level to another (Units 1 and 2) ;
- Students can explain basic systems or processes used for production of materials and artefacts (Units 1 and 3) ;

2. Use basic science process skills appropriate to the context of materials science and grade level:
  - Students make observations, measurements, and experiments (Unit 2) ;
  - Students develop and use categories to classify observations as well as analyse and interpret data (Units 1 and 2);
  - Students use reference sources to obtain information (Internet, textbook, handbooks, etc.) (Units 1 and 3);
  - Students make estimations and predictions based on observations and current knowledge (Units 1 and 2).
3. Use integrated science process skills appropriate to grade level:
  - Students identify variables and describe relationships between them (Units 2 and 3);
  - Students formulate questions and predictions based on existing knowledge and basic models and set aims to the inquiry tasks (Unit 2);
  - Students collect and record data (Unit 2);
  - Students analyse data and draw warranted inferences or explanations based on the basic models (Unit 2);
  - Students construct concept maps (Unit 4).
4. Increase motivation and interests:
  - Students maintain a sense of curiosity about natural phenomena (Unit 2);
  - Students maintain interest toward science studies and careers in science (Units 2 and 3);
  - Students voluntarily read web-pages, books and articles about material science (All units);
5. Demonstrate awareness of the social, history and society aspects of materials science:
  - Students understand that social and cultural forces have influenced the historical development of science and technology, especially from the point of view of materials, artefacts and their properties (Units 2 and 3);
  - Students understand how technological advances have influenced the progress of science and how science has influenced developments in technology (Units 2 and 3);
  - Students recognise the personal relevance of science and technology in daily life (Units 2 and 3);
  - Students respect the contributions of science and technology to the quality of human life (Units 2 and 3);
  - Students recognise the interdependence of science, technology, and society (Units 2 and 3);
  - Students recognise the possibility for studies and a career in science and technology (Units 2 and 3).
6. Communicate effectively using science language and reasoning:
  - Students use the language and concepts of science as a means of thinking and communicating (All units);
  - Students prepare written and oral reports describing the findings of investigations and the reasoning which led to the conclusions (Units 2 and 3);
  - Students report results of inquiry tasks honestly (Units 2 and 3).
7. Understand the nature of science and technology:
  - Students understand that science is an inquiry process used by humans to construct knowledge based upon observable evidence (Unit 2);
  - Students understand that technology is a creative discovery process used by humans to design usable artefacts (Units 1 and 3);
  - Students distinguish between science and technology (Units 1 and 3);
  - Students recognise the vital need for creative thinking and imagination in designing and conducting scientific inquiry and technological processes (Unit 3).

## 1.2 Recommended settings and pedagogical approaches

There are four main pedagogical approaches in the module:

1. Students will learn about materials and their properties by classification and other study activities.
2. They will learn about properties and behaviour of materials based on modelling activities and the Predict-Observe-Explain (POE) strategy in the science inquiry activities.
3. They will learn properties and use of materials and production of artefacts and properties of them through an industry site visit. During the site visit students will engage in activities before, during and after the visit.
4. Finally, the students will engage in learning through concept mapping. The students need to read and write during the activities, work together, and use ICT in several ways. There are several duties a teacher should complete before introducing the units to the students.

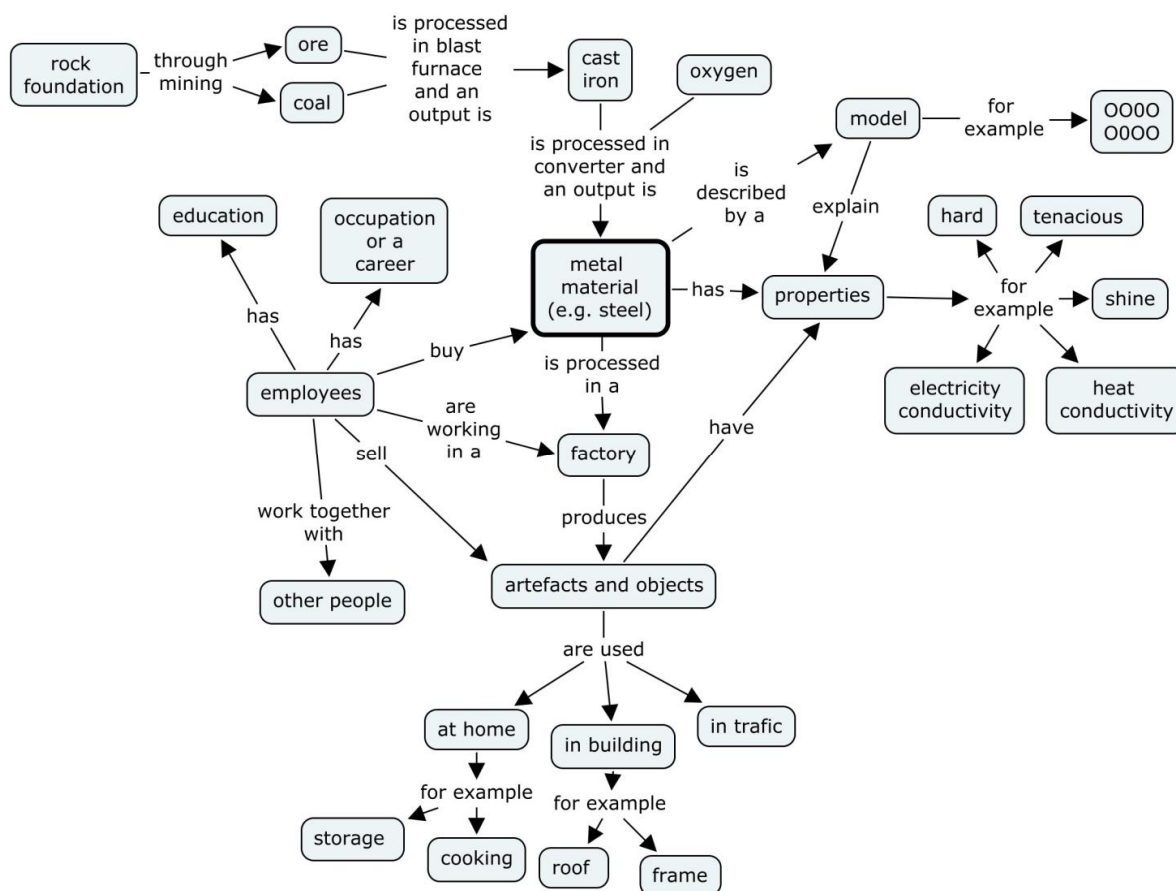
In the module, there are four units. Within Unit 1 students will become familiar with properties and use of materials around us. Moreover the students will become familiar with the microscopic model of materials. Wood and paper, plastic and metals will be used as examples of materials.

Unit 2 consists of inquiry activities. In the activities the students will first predict, then observe and finally explain. The titles of the activities are: Dropping test, Conductivity test, Ripping test, Heat conductivity test, and Bending test.

Unit 3 is an industry site visit. Before the visit the students become familiar with the site through web pages and prepare questions, which will be sent to the site. Students prepare also some interview questions considering manufacturing processes or occupations and careers at the site. The students will conduct short interviews during the site visit. These interviews will be used when writing the articles. Finally the students will become familiar with a modelling activity. The aim is to become familiar with manufacturing processes at the site. During the site visit the students complete their tasks. After the site visit the students write their articles and complete their modelling activities. The site visit will be evaluated through evaluation-discussion and a self-evaluation sheet as well as analysing of concept maps the students have created.

The concept map below is an example of a concept map, which can be created in Unit 4. The aim of Unit 4 is to help students to develop a holistic view of materials around us. From the map, content of all units can be seen.





*The concept map is one possibility to describe the material steel in a varied way.*

Different learning activities suitable for the designed units are described in the following chapters. Moreover, some unit-specific examples are presented.

Unit 1 is a theoretical introduction to materials and it introduces properties and the use of materials around us as well as microscopic and sub-microscopic models of materials. In the unit there are some students' assignments and simulations, which can be done individually or in a small group. The theoretical aspects can be presented by the teacher or they can be studied through a Jigsaw method or through use of Learning Centres. If the students are asked to read about theoretical aspects they can be guided to reading and writing activities as described later in this manual.

Unit 2 consists of inquiry activities where the POE strategy is followed. These activities could be organised using the Jigsaw method or through use of Learning Centres.

Within the industry site visit (Unit 3) several pedagogical approaches could be utilised in addition to students' assignments. For example, orientation to the industry site and questions to the staff of the site could be generated through the Think-Pair-Share strategy. Staff could be interviewed in the site in Learning Centres organised there. Moreover, students could be guided to work as journalists and to prepare articles based on their interviews. The students could search for relevant site related information on the Internet, read texts on the Internet, and write using word processors and process writing techniques.

Students could be guided to create a holistic view of the site and its contribution to the production of materials and artefacts through concept mapping using CmapTools software in



Unit 4. In addition to experiences during the site visit, information on materials, their use in production of artefacts, and properties of materials and artefacts could be found in newspapers, websites (of companies, Wikipedia) and in the brochures of companies, among others.

## 2 Materials have physical and chemical properties

There are many ways of classifying materials around us. We give below some illustrative examples without trying to present any comprehensive review. We start by describing where everyday materials come from: i.e. raw materials of industrial processes and their resources as well as processing of materials. Paper, metal and plastics as materials are described in Unit 1.

Raw materials are substances used as inputs to production or manufacturing. They range from natural entities such as copper or wood to man-made synthetics such as many plastics. Raw materials are processed to produce "semi-finished materials". These can be input into a new cycle of production and finishing processes to create "finished materials" or artefacts, ready for distribution and consumption.

Each material has certain properties and they can be recognised based on their properties. From the point of view of science education properties of materials can be classified to physical and chemical properties.

A chemical property is any of a material's properties that becomes evident during a chemical reaction; that is, any quality that can be established only by changing a substance's chemical identity. Simply speaking, chemical properties cannot be determined just by viewing or touching the substance; the substance's sub-microscopic structure must be affected for its chemical properties to be investigated. Chemical properties can be used for building chemical classifications. Examples of chemical properties include reactivity with other chemical substances, pH, heat of combustion, toxicity, etc.

Chemical properties can be contrasted with physical properties, which can be discerned without changing the substance's structure. However, for many properties within the scope of physical chemistry (and other disciplines at the border of chemistry and physics), the distinction may be a matter of researcher's perspective. Material properties (both physical and chemical) can be viewed as supervenient; i.e., secondary to the underlying reality. Several layers of supervenience are possible.

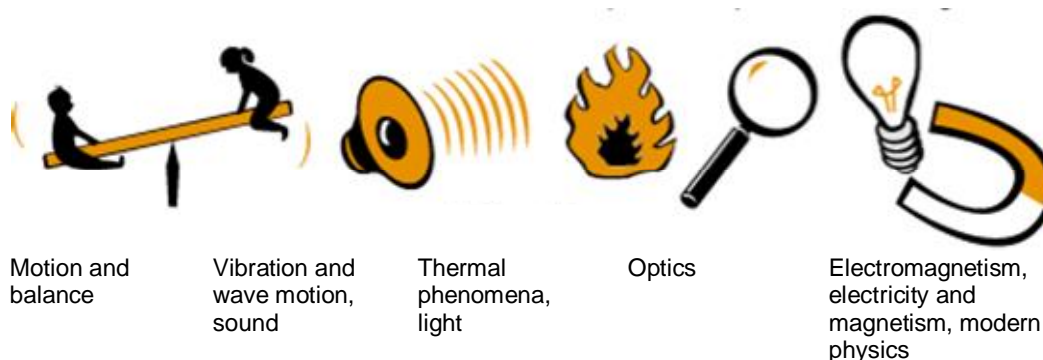
A physical property is any aspect of an artefact or substance that can be measured or perceived without changing its identity. Physical properties are referred to as observables. Often, it is difficult to determine whether a given property is physical or not. Colour, for example, can be "seen"; however, what we perceive as colour is really an interpretation of the reflective properties of a surface. It is useful to classify properties to the properties of items and properties of materials. A "cup" is an item and as such it has item properties: e.g., mass, shape, and temperature. Examples of material properties are density, resistivity, and thermal conductivity.

In everyday life we do not select objects through thinking, which materials have been used in the object. We choose objects based on the properties of objects. Knives are typically made of metal. So we just think what size and shape of a knife is appropriate in food making or eating, or e.g., in woodwork. Designers of a factory, which makes knives should think carefully about what kind of metal, raw material, should be used in knife production. While choosing the raw material the needs of the end user of the product should be considered, but also the industrial process used in manufacturing. Moreover, availability and price of the raw material should also be taken into account.

### 3 Pedagogical approaches

#### 3.1 Concept attainment through classification activity

We already make observations and classifications soon after we are born. Classification includes for example categorising people, artefacts, organisms and plants or phenomena into different categories. One can classify and arrange artefacts and phenomena on the basis of numerous different attributes. For instance, the material that an artefact is made of can be metal or plastic. Classification as a pedagogical approach is used in Units 1 and 3.



#### Classifying physical phenomena

Physical phenomena can be classified into motion, electric, thermal and sound phenomena, among others. Respectively, the attributes of materials can be classified into mechanical, electrical, optical and acoustic attributes. The classification may involve the formation of a concept hierarchy. Materials can also be classified on a more general level, for instance, into pure substances and mixtures of them.

#### Classification as a constructive process

Concepts are tools with which we are able to understand and analyse the world. When learning concepts, students should be supported to link the studied concepts to their previous knowledge. This presumes that a meaning for the concept has to be created before it can be attained and used in new situations. According to Joyce and Weil (1980: 25-60), people construct concepts naturally by classifying example data. Also in schools students attain the concept only after they have a sufficient number of examples related and unrelated to the concept. Students' concept formation can be supported by advising them to classify examples in class.

Classifying and arranging the data can be made easier, for example, with questions like: "What attributes do the artefacts/ phenomena have in common?" "What differences are there between the artefacts/ phenomena?" "How are the artefacts/ entities/ phenomena similar?" "Organise the artefacts/ entities according to their size/ mass/ roughness of the surface/ necessity." "In which order did things happen?" The teacher's questions help students to compare the artefacts/ phenomena under examination, and map their similarities and differences. The classification process is facilitated when learning begins with the students' own living environments and their previous experiences. For instance, months can be classified into winter, spring, summer and autumn months. The classification is based on the students' experiences of months and their temperatures and rainfalls.

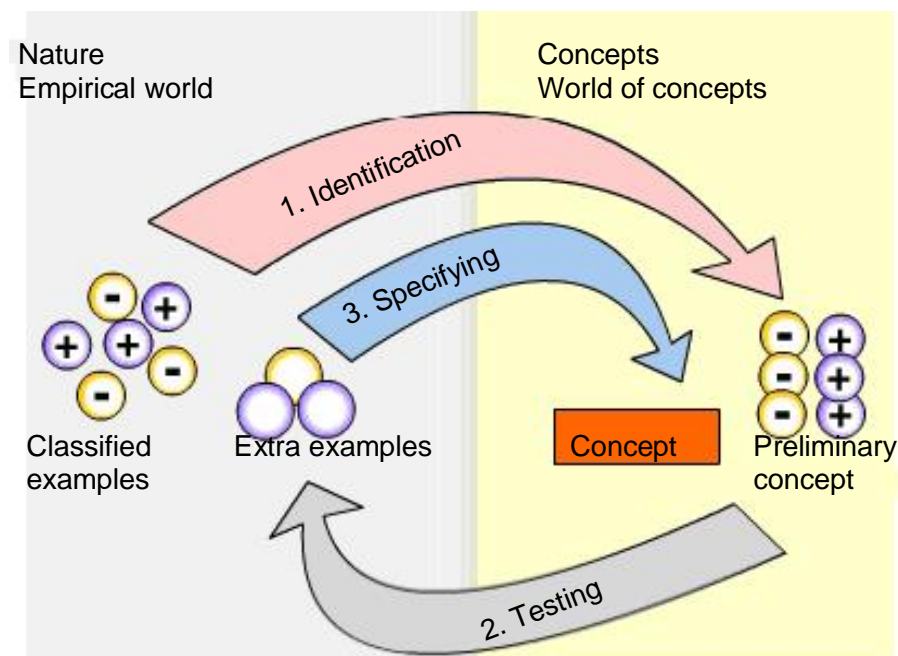
## Classification method

The following is a description of a concept attainment method based on classification. The method was developed by Joyce and Weil (1980) on the basis of the ideas presented by Jerome Bruner. The method is well suited for teaching especially concepts that have clearly separable attributes.

The method consists of classification, concept formation, and concept attainment phases. The concept or its preliminary definition is constructed inductively by classifying examples. Thus a derived preliminary concept is tested deductively with additional examples when attaining the concept. The phases of concept attainment through classification are described in the following using metal material as an example:

1. The teacher introduces examples related and unrelated to the concept, i.e. positive (+) and negative (-) exemplars. (The teacher shows metal artefacts (+) and plastic artefacts (-) to the students). The students identify the attributes that make the positive exemplars related to the concept and the negative ones unrelated to the concept (metal is shiny, metal is hard). The students present a descriptive definition for the concept (hard and shiny material).
2. The teacher gives the students more exemplars that the students identify to be either related or unrelated to the concept (metal).
3. After classifying the additional exemplars the concept is defined with the help of the teacher (metal is shiny, hard and tenacious material).

Classification can also begin with the teacher presenting the whole data at once and then asking the students to classify the data practically into categories. In this kind of classification process the students are more actively involved than in the previous method. This approach thus provides that the teacher is patient and guides the students. It is also possible to combine inquiry and classification activities.



*The phases of concept attainment through classification*



### 3.2 Models and modelling

A model is a representation of an idea, object, event, process, or a system (Gilbert & Boulter, 1998.). Nersessian (1999, 15) emphasises models as “mental representations with which a scientist carries out much reasoning and by means of which he/she thinks and understands through the lens of a conceptual structure”. From the point of view of science education models are parts of pupils’ learning processes, which help them to structure the new concepts with relation to their earlier conceptions. Models and modelling are emphasised in Units 1 and 2.

According to Gilbert and Boulter (1998, 56, 60), models can be classified on the grounds of their ontological status:

1. An internal representation (or a mental model) of a pupil is an individual’s private and personal cognitive representation, which is formed either on their own or within a group. By internal representation a pupil makes a model mentally available to oneself.
2. An external representation or an expressed model of a pupil is a mental model, which an individual tells to someone, writes etc. External representation makes a model available to others. It is believed that expressing changes the mental model.
3. A consensus model is formed in a social group, after discussion and experimentation. Published consensus models become scientific models. These scientific models represent the existing scientific conception of a phenomenon. Older consensus models, which have been produced in specific historical context and superseded, are called historical models.
4. Teaching models, particularly concerning the classroom situation, are planned models, which aim to help in understanding consensus, historical or curricular models. Students will become familiar with several teaching models in Unit 1.

According to Nersessian (1999), modelling is a fundamental form of human reasoning or model-based reasoning (MBR), a kind of “thinkaloud” reasoning process. From the point of view of learning, modelling is a part of a conceptual change process. Conceptual change is typically defined as learning that changes an existing conception (i.e., belief, idea, or way of thinking). Thus the new structure of knowledge forms as an outcome of a reasoned process, which is not accordant with a traditional account of reasoning.

Nersessian (1999, 6, 13-14) distinguishes three specific forms of model-based reasoning defining them as productive methods of conceptual change. The forms are 1) analogical, 2) visual or 3) simulative modelling. In analogical modelling the generative principles and constraints for a new model are sought from a source domain. The modelling happens by using generic abstraction to recognise potential similarities between disparate domains. The other way of modelling is to construct visual representations of the phenomenon. Visual representations make it possible to model the conceptual structure if the linguistic or other expedients are too limiting. External visual representations can be used to support people’s inner modelling processes. Model-based reasoning can also be simulative modelling, which means peoples’ ability to simulate physical situations or physical and chemical processes in their minds. A specific form of simulation is thought experimenting, which is based on narrative presentation of a real phenomenon. In thought experimenting the crucial advantage is to withdraw from the limits of the physical situation, and to link the conceptual and the experimental dimensions of human cognitive processing. Einstein used numerous thought experiments. By thought experimenting it is possible to perform demonstrations in schools that would have undesirable consequences in the real world (Nersessian, 1999, 6, 15-21). In Unit 2, visual and simulative modelling are emphasised. In material science and technology we use several levels of modelling including macroscopic, microscopic and sub-microscopic models. In this module we do not focus on theoretical/symbolic modelling. However, we may note that concept mapping can be interpreted as a basic level of modelling.



### 3.3 Learning by science inquiry

Inquiry-based or oriented science instruction has been characterised in a variety of ways over the years (DeBoer, 1991; Andersson, 2007) and promoted from a variety of perspectives. Some have emphasised the active nature of student involvement, associating inquiry with "hands-on" learning and experiential or activity-based instruction. Others have linked inquiry with a discovery approach or with the development of process skills associated with "the scientific method." Based on this short description it is easier to organise Units 1 and 2.

In a science inquiry activity students, typically in small groups, begin with a question, design an investigation, gather evidence, formulate an answer to the original question, and communicate the investigative process and results. In partial inquiries, which are also science inquiry activities, the students develop abilities and understanding about certain aspects of the inquiry process. Students might, for instance, describe how they would design an investigation, develop explanations based on scientific information and evidence provided through a classroom activity, or recognise and analyse several alternative explanations for a natural phenomenon presented in a teacher-led demonstration. Experiences in which students engage in scientific investigations provide the background for developing an understanding of the nature of scientific inquiry, and will also provide a foundation for appreciating the history of science. Students should understand that background knowledge and theories guide the design of investigations, the types of observations made, and the interpretations of data. In turn, the experiments and investigations students conduct become experiences that shape and modify their background knowledge.

In a science inquiry activity, the students are asked first to predict what will happen. However, it is not fair to ask students to make predictions in case they do not have any ideas or representations on the phenomena. Therefore, before the prediction phase, the students should be helped to recognise their own experiences and representations. For example, classification exercises can help students to recognise their existing representations based on their experiences. Writing down the prediction motivates students to look for an answer. Asking students to explain the reasons for their predictions gives the teacher indications of their theories.

Secondly, within the inquiry activity the students are asked to focus on observations and asked to write down what they do observe. Finally, the students are asked to formulate their explanation and to take account of the observation. After students have committed their explanations to paper, their ideas are discussed together. However, for primary school students, writing the answer can be a barrier to useful communication of ideas. Oral responses need to be managed so that other group members do not initially influence students (Use Think-Pair-Share, for example, before sharing with the whole group). Students may have difficulty explaining their reasoning. They are more likely to learn from observations that confirm their predictions. This cautions us to be careful that predictions are not wild guesses. A joint conversation about what we might expect to see, and why, based on the underlying science idea, could help avoid this trap (Palmer, 1995).

At the end of the previous millennium, there was wide interest towards learning or *inquiry in Web Based Learning Environments (WBLE)*. This is also an example of a *science inquiry* activity. In this framework, inquiry is understood as "*engaging students in the intentional process of diagnosing problems, critiquing experiments, distinguishing alternatives, planning investigations, researching conjectures, searching for information, debating with peers, seeking information from experts, and forming coherent arguments.*" (Linn, Davis, & Bell, 2004a, xvi).

In both cases, nature or internet as a source of information of inquiry or inquiry-based learning there are similarities. The following characteristics of inquiry-based learning can be emphasised:

- Learning is an active process, rather than the passive receiving of information. Students benefit from working on complex problems, which can be approached from different perspectives.
- Learning is a co-operative process and, therefore, students should be encouraged in interaction with others working on the same problem. Language is the most important carrier of these inquiry-supporting interactions.
- Conceptual understanding takes precedence over procedural efficiency. Knowledge about how to carry out a procedure is of limited value if the students do not have an understanding of how and when to use this knowledge.
- The teacher must be sensitive to students' previous knowledge of the phenomena under study. Some of these ideas might be valuable for learning, but others might be unproductive.
- Learning activities occur in interesting contexts.
- Problems that are relevant to students' experiences outside of the school setting enable them to make connections between what they learn outside of school and in class.
- Development of metacognitive skills enables students to take responsibility for managing and monitoring their own learning activities.
- Students have to be prepared for lifelong learning. Formal education should make the students able to learn for the rest of their lives, meeting the demands of a rapidly changing society.

### 3.4 Predict, Observe, Explain (POE) strategy in science inquiry

The Predict, Observe, Explain (POE) strategy was developed by White and Gunstone (1992) to uncover individual students' predictions about a specific event, and their reasons for making these, for example, within a demonstration. In the module, POE will be used within a science inquiry activity and guided with a student worksheet in Unit 2. The POE strategy can be used for finding out students' initial ideas, existing models, or internal representation, providing teachers with information about students' thinking, generating discussion, motivating students to want to explore the concept, and designing investigations.

A POE activity includes the following phases:

**Predict:** Students are presented a particular set-up of equipment with a worksheet, telling them what they are expected to do. Students then make predictions about what will happen, and a brief explanation of why they think that will be the correct outcome. It is not fair to ask students to make predictions in case they do not have any conceptual models or representations on the phenomena. Therefore before the prediction phase, phenomena should be discussed with the students to help them to recognise their representations. The students should become familiar with teaching models, described in figures. These figures are describing behaviour of metals, plastics and paper and they are already introduced in Unit 1. Moreover, classification exercises can help students to recognise their existing models based on their experiences.

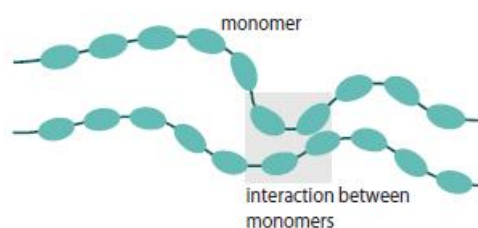
The models could be introduced to students by a story. The students could be told that some researchers have suggested that these three models explain the behaviour of paper, plastics and metal. Then the students are asked to investigate if they explain the behaviour of materials in some inquiry activities.

**Observe:** The activity is carried out, and the phenomena are observed and results of observations and measurements are written down.

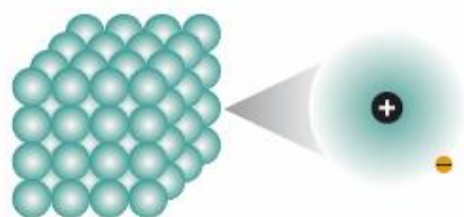
**Explain:** The students attempt to deconstruct the observed phenomena and explain why things happened the way they did. The idea is that the teacher plays a minimal role in the POE, leaving students to do most of the discovery. Instead of acting as The Leader, the



Paper is composed of cluster fibres and they of cellulose molecules having a polymer structure.



Plastic consists of chain-like polymer molecules. The polymer molecules have bound themselves weakly to each other.



Metal has a crystal structure. In the crystal the free electrons bind metal ions together.

teacher can act as more of a Master of Ceremonies, letting the main attraction -- the learning itself -- act as the "main event." The predicted outcomes may have turned out to be correct.

### 3.5 Activities supporting reading and writing

We present in this chapter some activities supporting reading and writing. These activities can be used within most pedagogical approaches including science inquiry (Unit 2) and site visit (Unit 3). Moreover, in Unit 1 students could be guided to read and write about materials, their production, and use.

Learning that is based mainly on reading and writing faces new challenges when learners look up information on the Internet. For instance, reading may entail copying web-based information on the notepad and writing in turn may entail pasting this information on the document-in-progress. In such cases, learners neither process information nor understand the meanings of new concepts - not to mention integrating these concepts within their own existing knowledge structure.

Thereby learning presupposes processing the available information by, for instance, reading and writing. In addition, concept and mind maps as well as knowledge structuring serve as effective means to process information (Bentley & Watts, 1989). In fact, by such a processing of information learners learn the skills and thinking necessary for fruitful information processing to take place. Moreover, when processing information in small groups, learners practise collaboration and communication skills as well. These skills are a pre-requisite for professionals serving in various fields of expertise (Tynjälä 1999).

Students may be encouraged and inspired to read and write by using modern information and communication technologies. By employing the Internet, students have access to meaningful information by consulting, for example, electronic books, hypertexts and hypermedia in CD-ROM format or diverse Web-based hypermedia documents, such as WWW pages. When looking up information in varied sources, students at the same time actively structure the flow of information they encounter into meaningful entities in order to be able to create a report on a given topic. Similarly, this exploration of information in varied sources forces students to evaluate the reliability of both the information and the sources they use. Student co-operation is here desirable, but teacher supervision and guidance is also needed.

#### Learning by reading

When studying material science, several types of texts can be used as sources of information, such as, course books, encyclopaedias, commercial materials, brochures and web-based texts. Once readers understand the meaning of a given text, this text first activates the previous knowledge readers have in mind on the subject and then initiates the learning process. This leads into constructing previous knowledge and new information to form a new combination altogether. Previous knowledge affects reading, and it is easier to understand a text that deals with a familiar topic. Moreover, contexts, topics and discussions affect interest and learning. For instance, when discussing, readers can be asked to tell what they already know about the topic and thereby design reading activities that foster learning both concepts and social skills.

Reading represents an active process in which the reader constructs new knowledge by processing the read text. At the first time when glancing over a text, the reader creates the 'first interpretation' that keeps being reinterpreted on subsequent readings. Both reading and

writing involve creating and modifying meanings. For instance, Tynjälä (1999) states that learning by reading, creating meanings, may be facilitated by carrying out writing exercises and discussions. The exercises that support reading learning may include the following (see also Baker, 1991):

- activating students' previous views and knowledge,
- comparing students' previous views and knowledge with the information featured in the text,
- dissecting the views presented in the text,
- applying the general principles presented in the text to imaginary practical settings,
- activating student learning in a small group (discussion, reflection)
- voicing critical opinions,
- writing a summary.

Developing learning strategies strongly relies on developing metacognitive skills. That is, readers who are able to process a text thoroughly are also capable of examining those strategies that they use for text processing and thereby choose a suitable strategy.

By means of the reading experience and with the help of the teacher readers develop several strategies for learning from a text. Both skilled and less fluent readers resort to reviewing in order to understand and memorise the contents of a given text. Moreover, many readers resort to looking for cue expressions and strategies dealing with the text structure. However, the most efficient strategies involve looking for the main points, organising the contents, taking notes, creating mind maps, drafting summaries, and anticipating what the text states next.

Strategies for active reading in the different stages of reading:

### *1. Preparing for reading*

Preparing for reading involves activating background knowledge, which means thinking of what one already knows about the subject. This information is jotted down on a piece of paper in the form of a bulleted list or by sketching a mind map. At the same time those types of questions are generated, which can be answered by reading the text. This preparing for reading makes the reading process easier and sets goals for the reader, which in turn help the reader to focus on the subject to be dealt with. In this way the active reader optimally manages his/her personal capacities.

### *2. Taking notes*

An active reader takes notes while reading by writing down the key words or creating a mind map on the most crucial issues in the text. S/he orders the contents by, for instance, recognising, classifying, comparing, and evaluating new information. In addition, s/he redefines the questions posed at the beginning and evaluates her/his work.

### *3. Connecting previous knowledge with new information*

After reading the active reader combines her/his previous knowledge with new learnt information. This combining can be facilitated either by writing about one's own thoughts after reading or answering those questions generated during the reading process.

When students read independently, they can be asked to write down key expressions and pose questions that come to mind when reading a given text. These questions voice what students have not understood. The questions can be collected on a white board or on a transparency for everybody to reflect on. While reading, students can create a mind map on the basis of the text. This mind map serves as a visual representation of the ideas generated

by the reading process and the connections between these ideas. The following lists some tangible activity types that can be carried out while reading:

- Add subheadings to the running text.
- Summarise the text; in other words, tell the main points in your own words. Summaries discuss the topics in full sentences instead of featuring bulleted lists. A summary is always genuinely created by the writer of an article or a study whereas a paraphrase merely lists another person's ideas.
- Skimming: Reading rapidly in order to get the general sense of what is written. The aim is to discover the main idea, to get the gist of it, the eyes run quickly through the text.
- Scanning: The aim is to find a particular piece of information. The effective reader must also be able
  - to anticipate both the form and the content
  - to identify main ideas
  - to recognise the relationship between the main ideas and their expansion
  - to infer from the text – read between the lines
  - to draw conclusions
  - to recognise the writer's purpose.
- Create a mind map or a conceptual map on the basis of the text. Of these two, a conceptual map displays in two dimensions the connections between the key concepts of a given field. Visually speaking, this involves linking the key concepts with arrows or lines, and naming these links in such a way that the naming characterises the link in question ("is an example of", "is part of", "comprises", "explains",...). Furthermore, a conceptual map clearly displays the concepts high up in the hierarchy. In contrast, a mind map is less rigid and thus does not necessarily feature named links connecting the key concepts.

Reciprocal reading aims at activating students to read and study in groups. Students are instructed to form pairs or small groups. After independently reading for a short while (for instance, one page), the following activities can be carried out:

- Each member of the group creates an outline on the basis of the read text and then explains to the rest of the group this outline (the main points of the text). Afterwards all the outlines are compared with each other and the goal is to focus on the main point of each outline.
- Each member of the group creates a mind map on the read text and presents it to the rest of the group. The created mind maps are studied and the aim is to find the essential points in each one.
- Each member of the group generates questions on the basis of the read text and asks the rest of the group these questions. The generated questions and answers are examined, and a couple of questions (1-3) are chosen to be presented jointly in class.

The visual display of the main points in a text is called a frame. The frame features the relations between the key concepts of the text, compares concepts with each other, juxtaposes or draws parallels between concepts and related examples and defines concepts. These frames may take the form of tables, sketches, figures and diagrams. In this sense, mind maps and preplanning tools serve as frames.

## Learning by writing

During the writing process, the writer develops both as a writer and a human being. Furthermore, expressing one's ideas, even by just keeping a journal, serves an effective way of testing how convincingly one is able to argue for one's points. This in turn enables the writer to retrospectively examine the development of the thinking process. In essence, developing one's thinking entails being conscious of one's thinking process. Writing



inextricably involves thinking, which secures it as a *cognitive* activity. It is common for writing to be a *solitary* activity by individuals since writing usually demands a high level of concentration. It is also a *linguistic* activity because the writer has to think about and be careful in selecting grammar structures and vocabulary, especially in interpreting “scientific” ideas. Overall, a teacher should consider that creating a written piece of work is a whole process, which involves learners in:

- gathering ideas - through reading,
- organising ideas into sentences and paragraphs; ideas need to be put into a logical order, paragraphs need a main idea and supporting points with a few details,
- drafting,
- editing,

Rivard (1994) has pointed out several factors that are crucial when trying to develop learning by writing. These factors involve, for instance, the requirements set for the student by the writing exercise, the learning atmosphere in class and the students’ metacognitive knowledge and skills. Thus such writing exercises that facilitate learning require the student to reprocess, question, interpret and synthesise issues and principles already learnt. In contrast, traditional exercises only orient students to represent previous information, copy ideas directly from a source, such as, for instance, a course book or a website.

Although writing serves as a natural way of creating meanings and viewing the world, writing tasks at school rarely motivate students. We all remember these all too familiar questions “How many pages?”, “Do I have to use full sentences?”, “Are bullet lists allowed?”. This apprehension to learning may also stem from how writing is equated with taking a test. Linna (1994, 16-19) lists tools that help transform writing tasks at school into pleasant experiences:

- Writing will not feel like taking a test as long as the atmosphere in class is such that it is easy to ask for help from the teacher and classmates.
- Students are instructed to write in small groups in class and keep the conversations going. Students are guided to give each other constructive feedback so that instead of focusing on what the writings lack they ask questions, such as, *How can I create a more concise introduction?*, *How can I emphasise the key concepts more?*.
- Students are guided to discuss the topics of their essays as talking (thinking out loud) aids understanding.
- Students are encouraged to structure the topic of an essay or an answer by creating a mind map or specifying questions.
- There is a purpose for writing, in other words, the prospective readers are other than the teacher.
- There will be no rigid timeline for writing that means that writing is viewed as a message to others rather than just a task to be completed.
- The class jointly explores how to analyse writing with techniques, such as mind mapping and organising information.
- Writing is integrated with the use of information and communication technology.

The most crucial issue in bringing about the motivation for writing is to have a recipient or at least an intended recipient and the means to publish the writings. Thus the texts are created for classmates or other potential readers rather than the teacher. The publication may take the form of a school bulletin, a booklet, or a website. Furthermore, the texts may be displayed in the science class, published on an online learning environment or on the Internet. During the writing process, writers can be supported by giving them the following questions for reflection:

- What else do I know about this issue?
- Should I try to explain some concepts?
- Should I give more grounds for my claims?
- Am I proceeding in the right direction?

- Does this take me to the conclusion that I want?
- Does the text fluently proceed from one topic to another?
- Have I provided enough evidence to convince a beginner?

Writing skills can be developed in science classes as well as in any other subjects' classes, and process writing represents one way of developing writing skills. Process writing views writing as a process that involves writing, reading one's own text, having others read the text, receiving feedback and editing the text (White & Arndt, 1991). This writing process may be divided into sub-processes that help manage writing more easily than when dealing with enormous units of information. Linna (1994, 35) lists the phases of the process of writing as follows:

1. Brainstorming and choosing the topic
2. Familiarising oneself with the topic (generating and choosing ideas, facts, views, goals, and visions)
3. Outlining the topic (analytic questions, mind maps) and sketching the structure for the text
4. Writing the first draft
5. Feedback (one's own views, peer feedback and teacher feedback)
6. Editing the text and thus creating the second draft
7. Creating the final publication version (double-checking language points and headings)
8. Publishing.

In fact, phases 2 and 3 serve in bringing about thoughts and ideas. The text is not supposed to be immediately ready as the goal is to create first an outline by using, for instance, the technique of mind mapping. During the brainstorming phase (1) it pays off to get feedback to be able to deepen the writing process and edit the text so that it can eventually be published.

Even though this model of process writing is only supposed to serve in visualising the steps involved in the writing process, this model may end up shackling the writing which, of course, does not serve the purpose. First and foremost, process writing is all about flexibility and emphasising the uniqueness of each student.

If students have no previous experience of process writing in their language classes, they have to be taught this technique by organising, for instance, short information sessions for this purpose. And even if the students master this technique, it still pays off to remind the students of the basic principles of process writing.

### **Activities focusing on reading and writing**

This chapter deals with activities that can be used within a MaterialsScience module that emphasises reading and writing. These activities have been designed to support active learning and writing. These projects characteristically result in report texts that outline the results of the given projects.

*Journals and blogs.* A basic method to write a story is to connect the story line with some sort of tangible action, and both journals and blogs fulfil this function. Small scale journals can be kept on themes that have been narrowed down. This sort of theme may in turn be connected with science themes, such as, for instance, "materials around us" or "the lifespan of a product". The following tangible example represents the field of energy consumption: *"Create a report on the materials you use over the period of a week and the times you use these materials. First, take notes, and second, at the end of the week think about the order in which you have to discuss relevant issues in order to give the reader a clear picture of your use of these materials. Illustrate your points by using graphics, for instance bar diagrams."*

*Studies based on interviews.* The previous example drew from the student's own actions as the source of information. Interviews are used to get information from other persons' actions. The following example features interview guidelines that have been formulated in accordance with the task prompts given for students. The media and daily discussions constantly keep bringing up the issue of the recycling of materials. Why and how should materials be recycled? *"Work with a partner and design an interview study. First, choose a viewpoint to recycling. Second, sketch 3-5 questions. Third, carry out interviews on your way home, on the street or at home to find out how people feel about recycling. Use an MP3 player or a tape recorder, or take notes while interviewing. Report your results in class. You may also write an article based on the interview results. Or you may publish a special issue on recycling that features everybody's articles. Prior to writing the article take a look at the types of article entries featured in magazines and find out about the constituents of an article."*

*Reports or articles on branches of material science industry.* When writing, information can be drawn from various course books and specialised publications, newspapers and magazines. Furthermore, on the Internet the home page of the company to be visited, as well as websites of various organisations, newspaper databases, and home sites of magazines and journals serve as excellent sources of information. In addition, information can be collected when visiting the industrial site. The following student instruction illustrates how writings can draw from written and digital sources.

*Draft a report on a material science industry. Collect relevant information on the field from course books, specialised publications, information booklets and home pages. Once you have gathered all the necessary information, organise this information. Think about the order in which you display information in the final report to ensure that your readers get a clear picture of the industry branch in question. You may orient your working process with the help of the following list of questions:*

*Goal-setting:*

- Which topic do I choose?
- What is the function of my study?
- What do I know about the topic in advance? Do I know anyone who works for this industry branch?
- What do I need to know about this industry branch?

*Sketching the plan:*

- In which different ways can I collect information on this industry branch?
- Which questions/problems are answered and discussed in my study? How do I formulate these questions/problems?
- Who can I go meet and interview? Whom can I call?
- Which sources do I use? Am I sure that this information is reliable?
- How do I take notes?
- How do I organise information?
- How do I visualise my results? How do I create these visualisations?
- How do I publish the report? Do I know how to use information technology?

*Evaluation:*

- Is the topic interesting and do I have enough knowledge on the subject? Is there information available?
- What do I have? What do I still lack?
- How do I display information?
- How do I organise and analyse information?

*Manuals.* Our world abounds in various types of manuals. Once you create a manual for another person, you at the same time learn the topic in question. The following instructions apply to creating manuals on the following topics, among others: recycling materials, use of

plastics, glass, metals, creating recycled paper. *“Work with a partner and create a manual on your topic. Before creating the manual, take a look at a manual, like one for an electric appliance. Pay especially attention to visualisation and the layout.”*

*Booklets.* The idea of a booklet is identical to the manual discussed above. The following student instructions may be used when creating booklets on how to safely use materials at home. A booklet can also be created based on the site visit. *“Create an updated and localised booklet, a basic guide for dealing with materials at home. First, jointly discuss which issues need to be covered in the booklet. After this is done, instruct the students to form groups and agree how to allocate each group an area of responsibility. Before you create the booklet, take a look at a booklet published by authorities. Pay careful attention to the booklet’s structure, foreword, headings, contents, visualisations and layout.”*

## How to Instruct the Students to Write an Article

### *The Structure of an Article*

In the Finnish comprehensive school the text types, which are common in the printed and electric media, are taught within the subject *Finnish language and literature* by the ninth grade. The students study to recognise different text types, for example articles from newspapers among others. In the seventh and eight grade students practise writing different text types, e.g. abstracts, essays and opinion texts. Students also read articles during the lessons in different school subjects.

In the eight grade book<sup>1</sup> of Finnish language and literature an article is defined in the following way: “Articles are texts which consider and introduce the subject in an extensive and multi-faceted way. An article is usually divided into different parts with subtitles, and the most fundamental content of it is often summarized into the first paragraph which is called ingress. An article is as matter-of-fact style like news, but unlike news, an article can also include a writer’s own opinions and assessments.”

At the beginning of the writing process the ninth grade students of a comprehensive school know the article as a text style. At first the students recapture what kind of text style an article is. Current articles from a magazine, e-magazine or a newspaper are used as examples. The subject of the example article should be easy, for example an animal species. The extent of the article should also be appropriate compared to the time resources. The students read the article and analyse the structure of it.

The main parts of the article are head title, caption, picture, picture text, body text and reference list. There can be one or more pictures with the picture text as a part of the article. The name of the writer is placed at the beginning of the article. The head title describes the topic and the viewpoint of the article. The caption leads the reader into the topic. It stands out from the rest of the text and is brief. The picture illustrates the text. It can be a photo, drawing or a graph. The picture text has a clear connection with the picture. In the body text there is a preface, a discussion and a close-up. The close-up takes an in-depth look at the subject. There also can be subtitles in the article, which divide the text into sequences. There can also be an information box as a part of the article, in which definitions and additional information can be found. In the reference list the information resources, e.g. books and websites are named. With the help of the reference list, a reader can look for additional information about the topic.

<sup>1</sup> Authors translated from the Finnish school textbook: Laine, P., Paasio, L., Valtonen, P. & Vartia, P. (2004) *Loitsu, Äidinkieli ja kirjallisuus 8*. Helsinki: Otava.

When the parts of the article are familiar to the students, they can continue analysing the structure of the article in a more specific way. The teacher and the students will discuss about what kind of articles the students prefer to read, and what the key character in an article is that attracts the students to read the article. After the discussion the students read an article chosen by the teacher. The students introduce the article to others and analyse the article by considering the following questions: What is the article about? Who wrote it and where has it been published? What is the aim of the article? What parts does the article have? What are the main issues in the text? What references are there? Students also assess what they consider to be the best things in the article, and what should be changed.

The titles of an article are studied by recalling the different title types. A title can be for example narrative or allusive. It can be a question, a citation, or a humoristic word play. Headlining and defining the perspective can be practised in the way that the students think up the head title, the subtitles, the caption and the picture text for an article, from which the teacher has removed these parts. The students think up the missing parts by reading the text of the body and looking at the picture.

### *Writing the article*

After, the students are taught the structure of an article, the writing process starts. The aim is to write in pairs or groups an article about a company to which the students are about to visit. The final articles will be published for example on the school web site.

At first the phases of the writing process and the timetable are reviewed with the students. The phases of the process are:

1. choosing the topic of the article and making pairs,
2. defining the perspective,
3. compiling the interview questions,
4. interviewing and making notes and taking pictures on the site visit,
5. writing the article on the basis of the notes made and the pictures taken on the site visit and
6. publishing the final articles.

The company, which the students are about to visit, is introduced to the students. The students are also introduced to some more specific branches about the company, e.g. the occupations of the employees, employees' education, the products of the company and international relations of the company. The students are allowed to think up what interests them also themselves. The students make pairs according to their interest. After the students have decided what they are about to write, they start to define the perspective of their article in co-operation with the teacher. The students search additional information from the Internet to be able to choose an interesting and suitable perspective for their article. If the topic of the article is for example 'International relations', the perspective can be 'The company's business abroad'.

After defining the perspective the pair searches for additional information from the Internet and other information sources and begins to compile the interview questions. Before this phase the students study what good interview questions are like. They are definite and clear. They have to give the interviewer enough information about the topic. They have to differ from each other and be specific enough. They have to have a clear connection to the perspective of the article. The questions that can only be answered 'yes' or 'no' should be avoided. There has to be a sufficient amount of questions, but the questions should not be too similar to each other.



The pairs compile the interview questions for their article and the teacher gives feedback about them to the students. Some of the questions are sent to the company in advance, thus the personnel of the company can prepare themselves better for the visit and take the students' wishes into account. If the personnel of the company know what the students are interested in, they can arrange to have the most suitable employees as guides and influence the schedule and contents of the site visit.

### *Conducting the interviews*

The students conduct the interviews on the site visit. Just before the visit the students study the interview technique. At the beginning of the interview the interviewer introduces him/herself to the one who is about to be interviewed and makes notes about the data received. The interviewer looks the interviewed person in the eye and asks the questions calmly. If there are two interviewers they can ask the questions in turns. They have to remember that one of them needs to make exact notes all the time. The interviewers listen to the answers carefully and ask additional questions if needed. If the interviewed person is about to deviate away from the subject, the interviewer has to try to lead him/her back on track. If the interviewer and the one who has been interviewed have agreed about taking photos, the interviewer takes one.

Besides the interviews the student-reporter gets information by observing everything s/he sees, hears and feels on the site visit. All observations and experiences are written down. The brochure given by the company is saved. If the student thinks that s/he is not getting enough information for the article, this is the last chance to change the perspective of the article.

After the site visit and the interviews it is time to write the article by computer. First the students write-up the information gathered from interviews in text form. Then they start reshaping the text to fit the structure of an article. After finishing the body of the text the students choose and write the other parts of the article. They also choose the pictures and compile the texts for them. Finally, the students define the titles and the other details. While writing the article the teacher gives feedback of, for example, the texts, the structure of the article, the appearance and grammar. The students send the final texts to the teacher by e-mail. The teacher evaluates the texts and agrees with the students about publishing the articles.

### *Writing an Article about the Site Visit*

Example of the phases and schedule of the writing process

#### I week

- |           |  |
|-----------|--|
| 1. lesson | Phases and schedule of the site visit project                                |
| 2. lesson | Studying the article as a text style, analysing the structure of the article |
| 3. lesson | continue analysing the article   |

#### II week

- |           |   |
|-----------|---|
| 1. lesson | Phases and schedule of the writing process, making working pairs, introducing the subject, telling the students to consider their perspective |
| 2. lesson | choosing the subject and defining the perspective, compiling the interview questions  |
| 3. lesson | defining the perspective, compiling the interview questions   |



## III week

1. lesson searching for information on the internet, studying the interview techniques, compiling the interview questions
2. lesson Site visit to Metso Automation  
- editing the article: conducting the interviews, taking pictures, and making notes
3. lesson writing the article

## IV week

1. lesson writing the article
2. lesson writing the article, the first article is ready
3. lesson defining the article, those who have not finished their articles have to finish them at home

## V week

- the students send the finished articles to the teacher by e-mail
- some of the articles will not be ready at all
- the articles may be published at school, for example on the school website

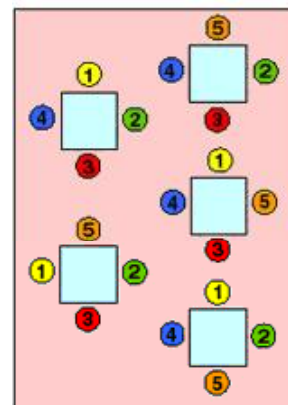
### 3.6 Jigsaw method

The jigsaw classroom is a co-operative learning technique. It could be used in Units 1, 2 and 3. The syntax is:

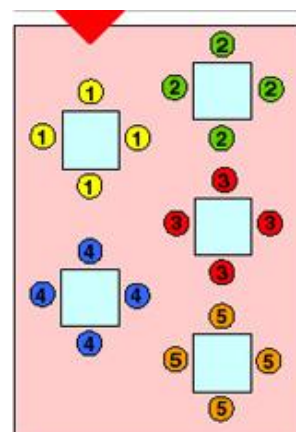
1. Instruct students to form *4-person jigsaw groups*. The groups should be diverse in terms of gender and ability.
2. Appoint one student from each group as the leader. Initially, this person should be the most mature student in the group. Give most important instructions to the team leaders.
3. Divide the lesson into 4-6 segments/inquiry activity places.
4. Assign each student one segment/ to be learned or inquiry activity to be completed, making sure students have direct access only to their own segment/inquiry activity.
5. Give students time to read over their segment/guidelines to inquiry activities at least twice so they become familiar with it. There is no need for them to memorise it.
6. Form *temporary "expert groups"* by having one student from each jigsaw group join other students assigned to the same segment. Give students in these expert groups time to discuss the main points of their segment / complete inquiry activities and to rehearse the presentations they will make to their jigsaw group. Sometimes it might be useful to appoint one student in each expert group as the leader. Give most important instructions to the team leaders considering for example the equipments used in the activity.
7. Bring the students back into their jigsaw groups.
8. Ask each student to present her or his segment to the group. Encourage others in the group to ask questions for clarification.
9. Float from group to group, observing the process. If any group is having trouble (e.g., a member is dominating or disruptive), make an appropriate intervention. Eventually, it's best for the group leader to handle this task. Leaders can be trained by whispering an instruction on how to intervene, until the leader gets the hang of it.

At the end of the session, give a quiz on the material so that students quickly come to realise what they have learned.

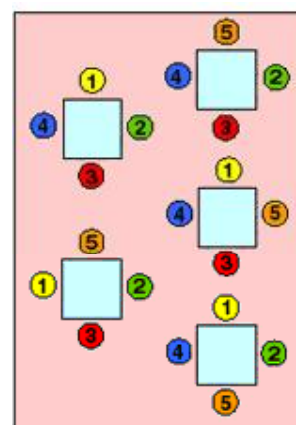
Make sure, that everyone at first reads the paper.



4-person jigsaw groups



4-person temporary "expert groups"



4-person jigsaw groups

### Example of use of jigsaw in science inquiry activity (Unit 2)

The aim of the activities in Unit 2 is to integrate the macroscopic and microscopic view of materials through the inquiry activities. The students will create an explanation for the structure, properties and behaviour of materials. These activities can be organised through the jigsaw method. During the activities students engage in collaborative groups with hands-on activities organised all around the classroom; the teacher glides between students, scaffolding, assessing, and observing along the way, giving help when needed.

There are five tasks/inquiry activities for the group to accomplish:

1. Dropping test
2. Electrical resistance/Conductivity test
3. Ripping test
4. Heat conductivity/insulation test
5. Bending test

The places where these tasks are completed are the places for *5-person temporary "expert groups"*. The students first become familiar with the inquiry activities in *5-person jigsaw groups*. If there are more than 25 students in the classroom there can be several similar expert groups. If there are less students in the classroom one inquiry activity '5. Bending test' could be skipped.

### Example of use of jigsaw in Unit 1

The aim of Unit 1 is to help students to become familiar with the properties and use of some materials. There is a learning material for this purpose.

There could be six tasks for the group to accomplish:

1. Properties of metals and a model that describe the microstructure of metal
2. Production and use of metals
3. Properties of plastic and a model that describes the microstructure of plastics
4. Production and use of plastic
5. Properties of paper and a model that describes the microstructure of paper
6. Production and use of paper

The students first become familiar with the inquiry activities in *6-person jigsaw groups*. Then they study and read about the topic of their *"expert groups"*. The students could also clarify issues by looking for information on the Internet. After the expert groups have become familiar with the themes mentioned above, the students in their jigsaw groups teach the mentioned themes to their peers in their jigsaw groups.

### 3.7 Think-Pair-Share

Think-Pair-Share is a co-operative discussion strategy. It gets its name from the three stages of student action, with emphasis on what students are to be doing at each of those stages.

The method could be used in Unit 1 and 3. The syntax is:

1) Think. The teacher provokes student thinking with a question or prompt or observation.

The students should take a few moments (probably not minutes) just to think about the question.

2) Pair. The teacher asks students to share their ideas with another student (pair). The students compare their mental or written notes and identify the answers they think are best, most convincing, or most unique.

3) Share. After students have talked in pairs for a few moments (again, usually not minutes), the teacher calls for pairs to share their thinking with another pair and later with the rest of the class. Often, the teacher or a designated helper will record these responses on the board or on the overhead.

We know that students learn, in part, by being able to talk about the content. But we do not want that to be a free-for-all. Think-Pair-Share is helpful because it structures the discussion. Students follow a prescribed process that limits off-task thinking and off-task behaviour, and accountability is built in because each must report to a partner, and then partners must report to the class.

Because of the first stage, when students simply think, the teacher should give them enough time for thinking: the students need time to think about their answers. As it is silent thinking time, you eliminate the problem of the eager and forward students who always shout out the answer, rendering unnecessary any thinking by other students. Also, the teacher has posed the question, and s/he has everyone thinking about the answer, which is much different from asking a question and then calling on an individual student, which leads some students to gamble that they will not be the one out of 30 who gets called on and therefore they do not think much about the question. Students get to try out their answers in the private sanctuary of the pair, before having to "go public" before the rest of their classmates. A student who would never usually speak up in class is in this way at least giving an answer to someone. Also, they often find out that their answer, which they assumed to be stupid, is actually not stupid at all...perhaps their partner thought of the same thing. Students also discover that they rethink their answer in order to express it to someone else, and they also often elaborate on their answer or think of new ideas as the partners share. These are reasons to employ Think-Pair-Share in order to structure students' thinking and their discussion.

#### Example of use of Think-Pair-Share in Unit 1

In the Unit 1 there are several open-ended exercises and classifications, which could be completed by the Think-Pair-Share co-operative discussion strategy.

#### Example of use of Think-Pair-Share in Unit 3

Questions which will be sent to the site could be created through Think-Pair-Share activity. It is important that the personnel at the site are familiar with students' preconceptions and their interests. When personnel prepare the presentation of the site, they can focus their presentation. Therefore, the students could first prepare questions, which will be sent to the site in pairs. Before formulating the questions the students should first think alone about what they would like to know about the products, processes and occupations of the site. Then they can prepare at least 5 questions in pairs. After that they could compare their questions with

another pair's questions, combine and develop the questions further and choose the 2 – 3 most interesting questions of the group. Finally, a classroom discussion is organised about the questions and the 5 – 8 most interesting questions will be selected from all the questions.

### 3.8 Use of Learning Centres in science inquiry activities

Science inquiry activities in Unit 2 could be organised in the form of Learning Centres located around a classroom. During the inquiries students are engaged with hands-on activities in groups organised all around the classroom; the teacher glides between students, scaffolding, assessing, and observing along the way, giving help when needed. This is what a classroom with learning centres looks like. A Learning Centre is an area in the classroom where students find authentic materials for studying a particular subject (Pattillo & Vaughan, 1992, p.13).

Learning Centres include multiple centres set up around the classroom with inquiry or other open-ended activities planned by the teacher based on the aims of the session. In these centres students work co-operatively with other students and teacher's constant presence and direction is not required. The activities allow planning, predicting, experimenting and making of conclusions. These activities lead students to meaningful learning. The teacher's role is to act as a facilitator, guide and supporter of students and provide scaffolding to assist students. Therefore, as the teacher supports them in their journey, learning centres provide an atmosphere where children are responsible for their own learning.

Learning centres are preferred for a number of reasons: they nurture autonomy, foster co-operative atmosphere, and facilitate "doing and understanding" (Pattillo and Vaughan, 1992, p.11). Students gain independence with this set-up because they are in charge of their own learning. Furthermore, because they are given the responsibility to make choices and practice some freedom within limits, they ultimately sharpen their decision-making skills. Overall, learning centres simply foster exploration, discovery, and the extension of learning.

Teachers typically prefer learning centres because they can freely observe and assess the students, they can meet individual needs, and they do not need multiple sets of materials. All the students do not use the same materials and equipments at the same time; therefore, the teacher needs only one or a few copies of a certain material or equipment, hence leaving much more variety in the classroom as a result. This is especially important in the activities of Unit 2: there is a limited amount of equipment needed in the activities at school. As the teacher watches each student closely, s/he is then able to assess his/her students' individual needs and plan accordingly.

A plan is necessary before organising the room for learning centres; behaviour problems can be prevented by strategic placement of the stations and the clarity of directions. For example, an active and a quiet centre should be separated from each other. On the other hand, compatible centres should be placed next to each other. Important decisions about centres concern numbers and time. A typical range on the number of students at each centre is between one and five. Time for each centre depends much on the difficulty of the inquiry activity. The teacher should evaluate difficulty of the task, difficulty of the use of apparatus, the length of time needed for reporting etc. While planning the timing of activities, an appropriate time for the activity could be from seven to fifteen minutes. Rotation between centres, can take some time, too. Therefore, a couple of minutes needs to be allocated for this, as well. The number of centres can range from two to ten. Before the teacher starts creating centres for the classroom, s/he needs to think about what s/he wants her students to learn. Choices, collaboration and variety help create learning centres with a student-centred atmosphere.

In addition to formal assessment, self-evaluation as well as informal and formal observations are the most frequently used assessment strategies. For example, use of portfolios could



make the routine collection of student's work from the centres into a personal folder more effective. This means that students sometimes make their own evaluations based on their work and the outcomes. Some things to consider during assessment, besides the finished product, are student use and the actual centre. The product is important, but how the student behaves and conducts her/himself should also be taken into account. For instance, the teacher should make sure if a student stayed at a task and co-operated with group members.

### **Example of use of Learning Centres in science inquiry activity (Unit 2)**

The aim of the Unit 2 activities is to integrate the macroscopic and sub-microscopic views of materials through the inquiry activities. The students will create an explanation for the structure, properties and behaviour of certain materials. These activities could be organised in learning centres. During the activities students are engaged in collaborative groups with hands-on activities organised all around the classroom; the teacher glides between students, scaffolding, assessing, and observing along the way, giving help when needed.

### **Example of use of Learning Centres in site visit (Unit 3)**

During the site visit the students interview the personnel. The members of the personnel could be located all around the room and the students could walk from one staff member to another. Consequently each staff member creates a learning centre and a group of students acquire knowledge in these centres through interviewing the staff.

Modelling activities could be done in learning centres during the site visit. In that case, students interview staff members working with materials at the site. After the interviews students outline a flow chart, which describes what the interviewed person is doing, what artefacts/materials s/he is using, how s/he is working with them and what is the output of his/her work.

### 3.9 Industry site visit

An industry site visit is an example of out-of-school learning utilising a school-industry partnership or school-industry/business links. An industry site visit consists of activities before the actual visit, activities during the visit and activities after the visit. Examples of these activities are described in Unit 3. Out-of-school visits make it easier to discuss cross-curricular perspectives, awake and deepen interest in sciences and show how humans apply sciences (Langsford, 2002). Moreover the students meet positive and diverse role models of scientists or workers in the industry (Bruce & Bruce, 2000). From the industry side Parvin and Stephenson (2004) mention three main reasons for school-industry partnership: 1) recruitment, 2) contributing to the community, and 3) enhancing reputation. In addition to previous advantages of a site visit, the site visit described in Unit 3 emphasises previously mentioned issues but also possibilities to learn material science and/or technology issues during the visit.

The industry site visit model is not rigid and allows variation within wide limits. For example, visits have been organised in connection with a wide range of school subjects, some projects even emphasising content outside the standard school curriculum with notable success. In other cases, teachers have allowed each student group to follow an individual time schedule while working within the industrial plant, whilst other student groups have each visited a different site. Visits have also been arranged in the form of two-day school camps. Last but not least, students themselves have contributed in various ways to the dissemination and acceptability of the idea of industrial visits and have raised funds necessary to support the activities. Already during the early phase of implementation of the idea, the time spent by a student as well as the net teaching time used for a visit had large variations showing clearly that there have been widely different forms of visits. This variation has only grown in the further development process indicating also the development of different new types of industrial plants, science centres etc.

The teacher has the overall responsibility for organising the visit, contacting parents, finding necessary resources, considering all safety precautions etc. The teacher's role in the practical phase of an industry site visit is like an adviser and consultant. However, case studies and experience show that the teacher has to work hard during the preparatory phase. Consequently, one of the key features of a successful visit is strong involvement of participating students at all stages of organising the visit. The activities begin with co-operative planning (including all aspects from choosing an interesting site to fund-raising) and finding information in advance on science and technology related student activities, which could be arranged during the visit. Visits where students have only a passive role during the visit should not be organised.

In a site visit model there are typically the following stages:

#### 1. Advance planning by teachers (0.5 – 2 hours):

- preliminary planning on general level by a group of teachers. Science/Physics and Chemistry teachers prepare students to study common materials and a student councillor in careers, occupations, and relevant education while a Mother Tongue teacher instructs in process writing and prepares for the role of a reporter,
- choosing the site to be visited.
- informing the school management team of the plans to organise a visit to get formal permission, when needed.

## 2. Teacher preparatory site visit (2 – 3 hours):

- finding a contact person at the plant,
- co-planning with the contact person at the plant (discussion about the preliminary goals of the visit dealing with the materials science and technology contents and occupations, description of student skills and abilities)

## 3. Advance preparation with students (1 – 2 hours):

- forming of student groups for project work,
- presenting preliminary goals for the visit, everyone involved must be made aware of the nature and purpose of the visit (students should be informed of its relation to and implications for their recent, current or impending studies),
- scaffolding when becoming familiar with the site and the industrial branch through company web site(s), marketing publications or annual reports,
- planning of the tasks and the way of reporting (preliminary questions to the staff at the plant, the structure of the report, ICT use in reporting, evaluation of the visit and the report),
- student groups co-planning the visit,
- groups prepare their project plans (goals, tasks, reporting plan),
- preparation and sending to the site contact persons questions on topics which are interesting for students,
- briefing of students on the visit (how they should behave, safety issues, etc.) They should be aware of what behaviour and work is expected of them at the venue
- informing parents/guardians on the visit and giving permission forms to be signed, when appropriate

## 4. Practical preparations for the visit (0.5 – 2 hours)

- When needed, after the organisational details of the visit have been confirmed, check that all relevant forms (including insurance if needed) are completed.
- Details of the visit, including the date, time, venue and programme details must be given to all involved, including
  - o the participating students
  - o accompanying teachers
  - o non-teacher supervisors
  - o any staff at the site to be visited who will receive/work with the students
- Discussion about tools needed in note making, interviewing, and photographing (e.g., pen and notebook, mp3 or tape recorder, still and video camera).
- Accompanying teachers and any non-teacher supervisors must be carefully advised about their roles and responsibilities.
- Participating officials need to know how their contributions will enhance or complement the students' work in school.
- It must also be ensured that everyone involved is aware of
  - o contingency plans for unforeseen circumstances
  - o first-aid facilities
  - o emergency telephone numbers.
- Members of the school office staff should be notified in writing of the dates and times of visits and the students and teachers involved.

## 5. The site visit (2 – 4 hours):

- introduction (plant, what employees are doing, what kind of people are working there),
- "sightseeing" around the plant,
- group or project work,
- different topics as agreed with students,

#### 6. Student group reports (1 – 2 hours):

- students prepare their reports, possibly in the form of a journal article
- contacting the site for comments,
- students present their reports,
- discussing what they have learnt and what could be improved.
- Work completed by students either during or subsequent to an educational visit should be displayed publicly in the school.
- articles could be published in a parent association journal, local newspaper, school website, etc.

#### 7. Evaluation and feedback with teachers and site representatives (0.5 – 1 hours):

The contact person at the site who hosted the visit and the staff who covered the activities should be thanked in an appropriate way. The teacher should also ensure that the senior management are informed of the progress of the visit and the conduct of the students so that appropriate comments/praise can be included in assemblies. A report of the visit should be included in the next parents' newsletter and the annual report of the school. Altogether, this phase should include

- evaluation of learning outcomes and student reports,
- evaluation of the ICT use during the project,
- evaluation of the overall arrangements and the practical running of the visit
- evaluation of student behaviour
- if the site visit will be organised again, what would/should be done differently

#### 8. Collecting ideas for planning future site visits (15 – 30 minutes).

The students may give feedback on the basis of Likert type questions with alternatives 1 to 4 to questions like

- 1) I learned physics and/or chemistry during the visit (little ... much)
- 2) I learned about working life and professions during the visit (little ... much)
- 3) I learned during the visit how physics and chemistry are applied in practice (little ... much)
- 4) I would like to have industrial visits at school (little ... much)
- 5) The industrial visit was in my mind (uninteresting ... interesting) and an open-form question "*What interested you most during the visit*"

There could also be a test on learning outcomes related to the list of the ones at the beginning of the Unit. Further feedback can be collected by analysing the student reports. Discussions with students may give important feedback not available otherwise.

It is most important that the co-operation with the contact person at the visited site will continue even over the final stages of the process.

#### **Students in a role of reporter during the site visit**

A teacher can help students to be active during the site visit for example through a role play. The students could, for example, adopt the role of a reporter who is making an article based on the site visit. When working as reporters, students first get acquainted with the topic, then plan the perspective of their own articles, and then find a specific focus for their topic, if needed. The students could become familiar with the site through its web site, through a marketing publication or through an annual report. Before the site visit students find out what a reporter does, and how s/he writes an article for a magazine, a newspaper or other publication. An example of a guide is published in Unit 3. Here co-operation with a Mother Tongue teacher is appreciated.

At the very early stages, it should be decided where the articles are published. It is more motivating for students if they have a feeling they are writing for an audience – not only for the teacher.

After getting familiar with the home page of the company to be visited, the students choose the perspective of their own article. It can be, for example, 'materials used in the production', 'raw materials and their origins', 'different occupations and the education needed for these occupations' or 'where the products of the site are used'. Students plan the aim of their article and what they want to tell their readers. Teacher can help students to focus on specific interesting aspects of the topic. The group members agree upon allocating the tasks and to which detail each group member is about to pay attention.

During the site visit students make notes about what they see and hear. They also interview staff members who are essential from the point of view of the subject of their article. Students ask the staff questions which they planned beforehand and which are relevant to the topic of their article. The answers to these questions should be written down carefully and recorded if possible. For example, students who are going to write their article about the occupations in the company should ask questions about the education, earlier jobs and present tasks of the personnel in the company.

Students also make notes about staff members working during the site visit. If students are allowed to take photos, they should photograph subjects that are relevant to the topic they are going to write their article about. Students should also make notes on what they have photographed. These notes can be edited so that they explain the pictures in the final article. If it is forbidden to take photos, students find out if they can use pictures from the company web site in their article.

After the site visit students write articles that are based on their notes and interviews and recordings of the interviews. The technique of writing an article is similar to process writing, because the writer lets his or her peers read his or her drafts, and elaborates them further after the feedback given to him/her. After the presentations of articles, they should be published.

### Concept map of the site

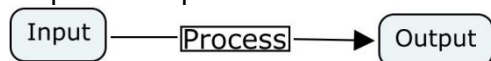
Finally, students' learning during the visit and the industry site visit procedure are evaluated by a questionnaire and analysing concept maps constructed by students.

The students prepare individually or in small groups preliminary concept maps reflecting their previous knowledge about material science issues, the processes at the industry site and professions at the site. The map is simply an answer to the question: What are the staff members doing at the site?

After the site visit the students revisit their preliminary concept map, evaluate it and prepare a new concept map. They will use the new knowledge learned during the visit while preparing the new map.

### Modelling a manufacturing process

Processes in manufacturing could be illustrated by a flow chart. In a flow chart, there is input, output and a process.



Within the site visit students can make a model of the whole site or a model of one post where one or two staff members are working. The students could also interview a staff member working with materials in the post. After clarifying the input, process and output the students make a flow chart, which describes the post. The following questions could be asked: What artefacts/materials is s/he using? What is s/he making from them? What is the output of his/her work?



## 4 ICT tools used in the unit

In the module students search for relevant information over the Internet, read texts on the Internet, and write using word processors and process writing techniques. Concept maps are drawn and analysed using CmapTools software. Concept-mapping using CmapTools is analysed next in detail:

Novak and Gowin (1984) designed a concept map technique alongside their research into human learning and knowledge construction. Novak (1977) proposed that the primary elements of knowledge are concepts and relationships between concepts are propositions. Novak (1998) defined concepts as “perceived regularities in events or artefacts, or records of events or artefacts, designated by a label.” Propositions consist of two or more concept labels connected by a linking relationship that forms a semantic unit. Concept maps are graphical two-dimensional displays of concepts (usually represented within boxes or circles), connected by directed arcs encoding brief relationships (linking phrases) between pairs of concepts forming propositions. The simplest concept map consists of two nodes connected by an arc representing a simple sentence such as ‘water is liquid,’ but they can also become quite intricate.

Concept maps are effective in representing and communicating knowledge. They help students to organise their thinking and to summarise subjects of study. From an educational perspective, a growing body of research indicates that the use of concept maps can facilitate meaningful learning (Coffey et al., 2003). Concept maps have also been shown to be of value as a knowledge acquisition tool during the construction of expert systems (Ford, Coffey, Cañas, Andrews, & Turner, 1996) and performance support systems, and as a means of capturing and sharing experts’ knowledge (Coffey, Hoffman, Cañas, & Ford, 2002). ICT facilitates the construction of concept maps in the same way that a word processor supports the task of writing text.

CmapTools is an ICT tool which facilitates the building and manipulation of concept maps. More info about use of CmapTools can be found on the CmapTools help Website (<http://cmap.ihmc.us/download/>).

## 5 Hints and tips

During the activities, the students use web pages and other resources, which have been published by companies. Therefore, the teacher has to be aware that there are commercial interests in the information sources.

## 6 Evaluation tasks for individual activities or individual Units or whole modules (including assessment rubrics)

The evaluation of student learning is based on the list of intended learning outcomes at the beginning of this teacher guide. These will be identified for each unit and concretised by observing the way teaching and studying has taken place. When writing the test items the teacher takes into account how s/he has chosen the contents etc. For example, for Unit 1 common materials found at home, like metals, plastics and paper, are used. Consequently, the teacher could test if the students can:

1. Understand the basics of science concepts, principles, and systems in the contexts of materials and properties of them (as appropriate to grade 9):
  - can identify metals, plastics and paper/cardboard and know the terminology used in describing them;
  - understand the meaning of the basic materials science concepts and principles: a material has certain physical and chemical properties and materials are distinguished from each other based on their properties; materials are used for production of artefacts and materials are selected to the artefacts based on their properties;
  - understand basic microscopic models, which describe the structure of matter, properties and behaviour of matter, especially in the case of metals, paper and plastics;
  - understand the ways of representing materials on different levels (macroscopic, microscopic, and sub-microscopic level as well as on the symbolic level), and can relate to and shift from one level to another;
  - can explain basic systems or processes used for production of materials and artefacts;
2. Use basic science process skills appropriate to the context of materials science and grade level:
  - develop and use categories to classify observations as well as analyse and interpret data ;
  - use reference sources to obtain information (Internet, textbook, handbooks, etc.);
  - make estimations and predictions based on observations and current knowledge.
3. Use integrated science process skills appropriate to grade level:
  - identify variables which describe properties of materials and relationships between them;
  - formulate questions and predictions based on existing knowledge and basic models and set aims to the inquiry tasks;
  - collect and record data;
  - analyse data and draw warranted inferences or explanations based on the basic models;
  - draw concept maps.
4. Demonstrate motivation and interests:
  - demonstrate interest toward science, science studies and careers in science
  - voluntarily read web-pages, books and articles about material science;
5. Demonstrate awareness of the social, history and society aspects of materials science:
  - understand that social and cultural forces have influenced the historical development of science and technology, especially from the point of view of materials, artefacts and their properties;
  - understand how technological advances have influenced the progress of science and how science has influenced developments in technology;
6. Communicate effectively using science language and reasoning:

- use the language and concepts of science as a means of thinking and communicating;
7. Understand the nature of science and technology:
- understand that technology is a creative discovery process used by humans to design usable artefacts;
  - distinguish between science and technology

An example of a cognitive test is provided in the next page

## 7 References


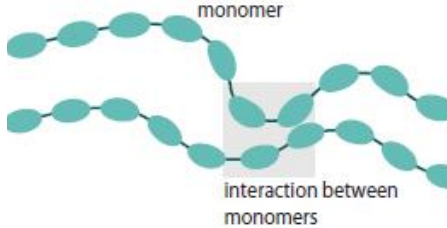
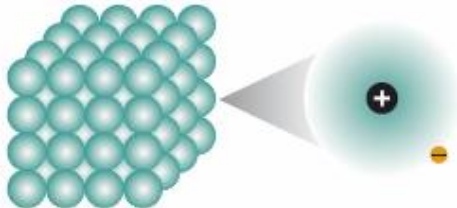
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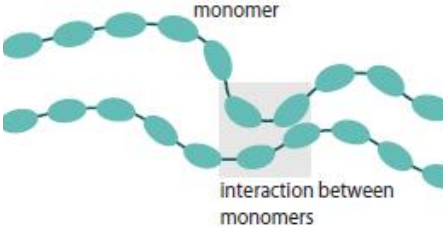
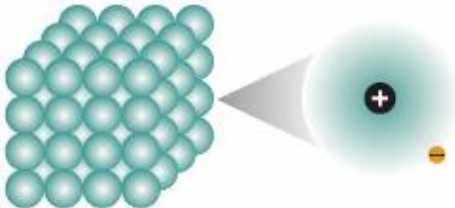


## 8. Appendices


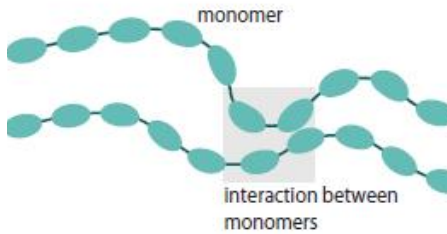
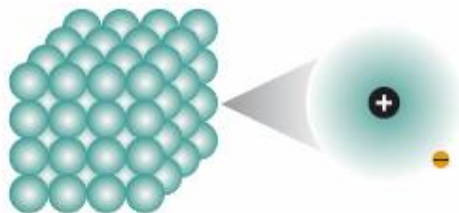
## Dropping test

	 <p>Paper is composed of cluster fibres and they of cellulose molecules having a polymer structure.</p>	 <p>Plastic consists of chain-like polymer molecules. The polymer molecules have bound themselves weakly to each other.</p>	 <p>Metal has a crystal structure. In the crystal the free electrons bind metal ions together.</p>
<b>Predict</b> What will happen in the test? Pay attention to the spot where the stone hit the material. Base your prediction on the micro models of the materials.	<i>There will rip so that it will form a long hole. The paper consists of cluster fibres. The fibres consist of cellulose molecules that have lot of interactions between them making the fibre hard. Between the cluster fibres there are less interactions and so the paper will rip between fibres and along them rather than across them breaking the fibres.</i>	<i>Plastic foil is elastic. It is composed of polymer molecules that are aligned at some places and there experience weak interactions. When the ball hits the foil the chain-like molecules straighten and the foil stretches. When the stretching ends, the molecules will return to their original curvy positions and the ball bounces off.</i>	<i>First there will be a little dent in the aluminium foil. The free electrons in between the metal atoms act as a "glue" that holds the foil together. When a ball hits the foil, the atoms and electrons with them move to new positions. The electrons work as a "glue" in the new position as well and prevent the foil from breaking. If the ball's velocity is high enough, it will go through the foil pushing the atoms apart.</i>
<b>Observe</b> What happens in the test?	<i>The paper broke and a linear hole was formed.</i>	<i>The plastic foil was strained under the ball but recovered and the ball was thrown back. The plastic foil didn't break easily.</i>	<i>First a small dent forms at the spot where the ball hit the aluminium foil. When the ball was dropped from a higher position, the foil broke.</i>
<b>Explain</b> How can the observed phenomena be explained with models? How are the particles of the material organised in the material?	<i>The interactions between fibres are weak. That is why the paper more easily rips in the direction of the fibres.</i>	<i>When the ball hits the foil the chain-like molecules straighten and the foil stretches. When the stretching ends, the molecules return to their original curvy positions.</i>	<i>The free electrons in between the metal atoms act as a "glue" that holds the foil together. When a ball hits the foil, the atoms and electrons with them move to new positions and hold them.</i>


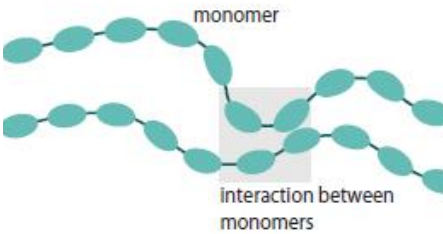
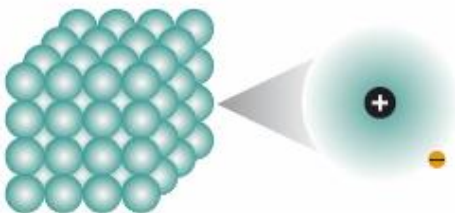
## Conductivity test

	 <p>Paper is composed of cluster fibres and they of cellulose molecules having a polymer structure.</p>	 <p>Plastic consists of chain-like polymer molecules. The polymer molecules have bound themselves weakly to each other.</p>	 <p>Metal has a crystal structure. In the crystal the free electrons bind metal ions together.</p>
<b>Predict</b> What will happen when the materials under study are one by one connected to the circuit? Base your prediction on the micro models of the materials.	<i>There are no free electrons in paper to conduct electricity. All the electrons are located in the cellulose molecules. Thus paper will not conduct electricity.</i>	<i>Plastic doesn't have any free electrons to conduct electricity. All the electrons are located in the polymer molecules. Plastic doesn't conduct electricity.</i>	<i>There are free electrons in metal that can move around in the lattice. This means that metal will conduct electricity. The lamp will be lit.</i>
<b>Observe</b> What happens in the test?	<i>When a piece of paper was connected to the circuit, the lamp was not lit.</i>	<i>When a plastic object was connected to the circuit, the lamp was not lit.</i>	<i>The lamp went on when a piece of metal was connected to the circuit.</i>
<b>Explain</b> How can the observed phenomena be explained with models? How are the particles of the material organised in the material?	<i>Paper does not conduct electricity since there are no free electrons to do so.</i>	<i>Plastic material doesn't conduct electricity since there are no free electrons in plastic to do so.</i>	<i>The lamp went on because metal conducts electricity. This is because there are free electrons in metal that can move freely around the metal lattice.</i>


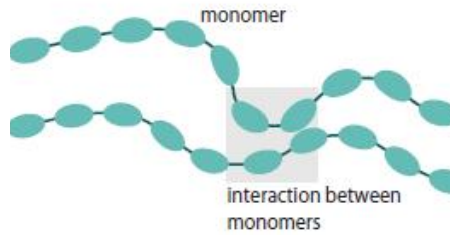
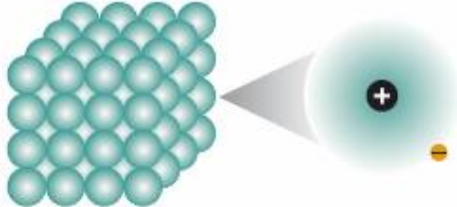
## Ripping test

	 <p>Paper is composed of cluster fibres and they of cellulose molecules having a polymer structure.</p>	 <p>Plastic consists of chain-like polymer molecules. The polymer molecules have bound themselves weakly to each other.</p>	 <p>Metal has a crystal structure. In the crystal the free electrons bind metal ions together.</p>
<b>Predict</b> What will happen in the test? Base your prediction on the micro models of the materials.	<i>The fibres in paper are mostly aligned in one direction. Paper will rip linearly and more easily in the direction of the fibres because there are only weak interaction between the fibres.</i>	<i>The polymer chains in plastic are not aligned. The plastic foil will behave similarly regardless of the direction of tearing. If the force is not too strong, the polymer chains first straighten and then when no force is used, they will return to their original positions.</i>	<i>The metal lattice is similar everywhere so the direction of tearing doesn't make a change.</i>
<b>Observe</b> What happens in the test?	<i>Paper rips more easily and straight in the other directions. When ripped in the other direction, the rip tends to turn.</i>	<i>Plastic first stretches and then rips unevenly.</i>	<i>Aluminium foil rips as easily and unevenly from all directions.</i>
<b>Explain</b> How can the observed phenomena be explained with models? How are the particles of the material organised in the material?	<i>The interaction between fibres is weak and thus they disengage and the paper rips in their direction. Paper rips unevenly when it is ripped perpendicular to the direction of the fibers because the fibers are strong and don't break.</i>	<i>When the plastic foil is first pulled the polymer molecules straighten and the material stretches. When more force is used the chains start slipping by each other as their weak interactions don't hold them together anymore. Because the chains are not well ordered the phenomenon is the same when ripping in all directions.</i>	<i>The metal lattice is the same in all parts of the metal so ripping is similar in all directions. Enough force causes the atoms to move apart although the free electrons acting as a "glue" resist some force.</i>


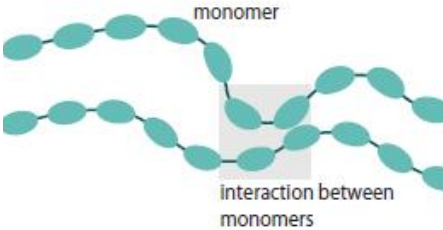
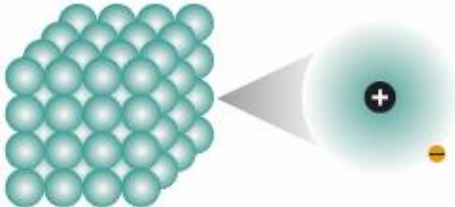
## Heat conductivity test

	 <p>Paper is composed of cluster fibres and they of cellulose molecules having a polymer structure.</p>	 <p>Plastic consists of chain-like polymer molecules. The polymer molecules have bound themselves weakly to each other.</p>	 <p>Metal has a crystal structure. In the crystal the free electrons bind metal ions together.</p>
<b>Predict</b> What will happen in the test? Base your prediction on the micro models of the materials.	<i>Paper is lacking the free electrons which have a central role in thermal conductivity. Paper is also a very porous material on microscopic level as well as submicroscopic level where there is lots of space between atoms. Paper will conduct heat slowly and it will take a long time for the butter to melt.</i>	<i>There are no free electrons in plastic that have a central role in thermal conductivity. In plastic the polymer chains are not very tightly packed which also makes it less efficient in conducting heat. It will take a long time for the butter to melt.</i>	<i>In the metal lattice the atoms are tightly packed and they collide very often and heat is transferred from atom to atom. More importantly there are also free electrons in the metal lattice which transport heat very fast around the metal. Butter on the metal will melt first.</i>
<b>Observe</b> What happens in the test?	<i>The butter on the cardboard melts slower than on metal.</i>	<i>The butter on the plastic spoon melts slower than on metal.</i>	<i>The butter on metal melts first.</i>
<b>Explain</b> How can the observed phenomena be explained with models? How are the particles of the material organised in the material?	<i>The cardboard conducted heat very slowly because it hasn't got free electrons and it's very porous which also slows down the conductivity.</i>	<i>There were no free electrons in plastic that were needed for efficient thermal conductivity. In plastic the polymer chains also were not very tightly packed which also made it less efficient in conducting heat.</i>	<i>In the metal lattice the atoms are tightly packed and they collide very often and heat was transferred from atom to atom. More importantly there were also free electrons in the metal lattice which transported heat very fast around the metal.</i>

## Bending test

	 <p>Paper is composed of cluster fibres and they of cellulose molecules having a polymer structure.</p>	 <p>Plastic consists of chain-like polymer molecules. The polymer molecules have bound themselves weakly to each other.</p>	 <p>Metal has a crystal structure. In the crystal the free electrons bind metal ions together.</p>
<b>Predict</b> What will happen in the test? Base your prediction on the micro models of the materials.	<i>When paper is rolled up it will bend really well but when the weak interactions between the fibers fail, paper will stay curvy.</i>	<i>Plastic bends well and when no stress is applied, it will return from the bend. When plastic is bended the polymer chains straighten or curve up and when no stress is applied they return to their original position.</i>	<i>Metal can be bended back and forth quite a lot. When the atoms move to new positions they bring with them the free electrons. In the new position the electrons work as a "glue" as they worked in the previous position as well. So the atoms will not return to previous positions and thus the metal stays bended.</i>
<b>Observe</b> What happens in the test?	<i>Paper is bended easily but doesn't return from the bended position very well.</i>	<i>Plastic bends well and returns back to original shape.</i>	<i>Metal can be bended a lot but doesn't return to it's original shape.</i>
<b>Explain</b> How can the observed phenomena be explained with models? How are the particles of the material organised in the material?	<i>The net-like fibre structure of paper stands some bending but when the bending is too strong, the weak interactions between fibres fail and the paper stays bended.</i>	<i>The net-like structure of the polymer molecules can take a lot of strain. First the polymer molecules straightened and when the material wasn't bended anymore, they returned to their original positions and the plastic recovered its original shape. Too strong bend overcomes the interactions between the molecules and they move to new positions.</i>	<i>When metal was bended, the atoms moved to new positions where the free electrons held them together just like in the previous position. There was no need for the atoms to return to their original positions so metal holds its new shape. The electrons kept the material from breaking when atoms moved to new positions.</i>



	 <p>Paper is composed of cluster fibres and they of cellulose molecules having a polymer structure.</p>	 <p>Plastic consists of chain-like polymer molecules. The polymer molecules have bound themselves weakly to each other.</p>	 <p>Metal has a crystal structure. In the crystal the free electrons bind metal ions together.</p>
<b>Predict</b> What will happen in the test? Base your prediction on the micro models of the materials.			
<b>Observe</b> What happens in the test?			
<b>Explain</b> How can the observed phenomena be explained with models? How are the particles of the material organised in the material?			

Name:
MaterialsScience – content knowledge test

Answer the questions below for all materials and all the items.  
It is important that you fill in all the spaces in the table. You can write the same answer in several locations.

Material Item	Metal		Paper		Plastic	
	Iron nail	Aluminium foil	Copy paper	cardboard box	Plastic bag	Plastic bucket
Properties of an item made of the material?						
What other items are made of this material?						
How could you eyes blinded recognize the material?						
What is the raw material for this item?						
Describe the structure of this material. <b>Draw a picture.</b>						

Information on student learning should also be acquired through self-evaluation. There is a self-evaluation form at the end of the student booklet. Students evaluate their learning during the site visit, by answering to the following questions:

	Very little			Very much	
I learned physics and chemistry at the site	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I learned how physics and chemistry are applied in practice in efforts to innovate and develop new products	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I learned about properties of materials	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I learned about how the site tests the quality of the materials it is using in its products	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I learned about how the site processes the raw materials and makes products out of them	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I learned about products and their properties	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I learned about working life and professions during the visit	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I learned about professions during the visit	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I learned about education needed in the professions during the visit	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I'd like to have site visits arranged in my school more often	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I liked this site visit	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

For each of the following, please describe some aspects that interested you during the visit.

- Science and Technology and their role in society \_\_\_\_\_
- Manufacturing processes \_\_\_\_\_
- Converting raw-materials into products \_\_\_\_\_
- Occupations and careers related to science or technology \_\_\_\_\_
- Connections between the natural environment and human activities \_\_\_\_\_

Similar questions could be developed also for other units. When using concept maps in studying, evaluation can be realised based on students' concept maps and a pre- and post-test. CmapTools facilitates also the comparison of concept maps. Information about the use of CmapTools for comparison of two concept maps can be found on the CmapTools Help Website (<http://cmap.ihmc.us/Support/Help/>). Usually, the quality and sophistication of a concept map is evaluated on the basis of the number of correct concept-to-concept links.

The evaluation of the unit is based on student and teacher interviews and observations. Of course, the goals expressed in school curriculum and information on student learning outcomes should be used in this evaluation.



This learning material has been designed as a part of European Union 6th framework university-school partnerships project (SAS6-CT-2006-042942-Material Science, <http://lsg.uci.ac.cy/materialsscience/>). The project aims to design and implement research-based ICT-enhanced modules for comprehensive schools in specific domains related to materials science. These modules aim to emphasise the inquiry based science learning, the active student engagement, the motivation and the collaborative learning.

Following experts have participated the module development:

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- Experts modifying Finnish module to Greece or experts participating peer-review study visits: Petros Kariotoglou, Theodora Polatidou, Anna Spyrtou and Tassos Zoupidis (University of Western Macedonia, Greece); Costas Constantinou, Yiannis Hadjidemetriou and Nikos Papadouris (The University of Cyprus); Roser Pinto (Autonomous University of Barcelona, Spain) and Hans Niedderer (Mälardalen University, Sweden)

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