Materials Science

# Finnish Module of the MaterialsScience[[1]](#footnote-1) Project: Helping Students to Become Familiar with Materials around Us through Inquiry, Site Visits and Reading and Writing Activities

Jari Lavonena, Veijo Meisaloa, Annika Ampujaa, Kalle Juutia, Jarkko Lampiselkäa, Antti Laherto d,   
Anni Loukomiesa, Jan Janssona,Tomi Alakoskib, Hilkka Koljonen-Toppilac, Timo Kärkkäinenc,  
 Marja Montonene, & Lasse Vanhanenf

aDepartment of Applied Sciences of Education, University of Helsinki, Finland, bInformation Bureau of Finnish Industry, cHelsingin normaalilyseo Teacher Training School, University of Helsinki, Finland, dDepartment of Physics, University of Helsinki, Finland, eNational Board of Education, Finland, and fViikki Teacher Training School, University of Helsinki, Finland.

Theme of the module: materials around us   
Age of the students: 10-16 years  
Anticipated teaching time: Unit 1: 5 hours, Unit 2: 5 hours



Table of Contents

[Finnish Module of the MaterialsScience Project: Helping Students to Become Familiar with Materials around Us through Inquiry, Site Visits and Reading and Writing Activities 0](#_Toc242693332)

[A. Teacher’s Guide 2](#_Toc242693333)

[1. Introduction to the module. The rationale of the module. Relevance of the module in terms of developing an awareness of the role of Science in social Contexts. 2](#_Toc242693334)

[2. Connection of this module to other modules in project *Materials Science* 3](#_Toc242693335)

[3. Background Information 3](#_Toc242693336)

[4. Pre-requisite Prior Knowledge of Students 4](#_Toc242693337)

[5. Aims of the module 6](#_Toc242693338)

[6. Pedagogical approach and context 7](#_Toc242693339)

[6.1 Materials around us as a context 7](#_Toc242693340)

[6.1.1 Paper as a material 8](#_Toc242693341)

[6.1.2 Plastics as materials 8](#_Toc242693342)

[6.1.3 Ceramics as materials 9](#_Toc242693343)

[6.1.4 Metals as materials 9](#_Toc242693344)

[6.2 Learning by science inquiry 11](#_Toc242693345)

[6.3 Materials science related activity-based site visit 13](#_Toc242693346)

[6.4 Activities supporting reading and writing 19](#_Toc242693347)

[7. Relevant ICT tools 26](#_Toc242693348)

[7.1 Tool applications 27](#_Toc242693349)

[7.2 Computer-assisted inquiry 28](#_Toc242693350)

[7.3 Using ICT in modelling 28](#_Toc242693351)

[7.4 Communicating with ICT 29](#_Toc242693352)

[8. Common student difficulties 30](#_Toc242693353)

[9. Monitoring Student Learning: 30](#_Toc242693354)

[9.1 Instruments for the assessment of learning outcomes 30](#_Toc242693355)

[9.2 Monitoring student engagement and motivation 30](#_Toc242693356)

[10 Rationale of Extension Activities 42](#_Toc242693357)

[11 Other Useful information – List of Relevant Articles, Links to Web Sites 42](#_Toc242693358)

[12 References 43](#_Toc242693359)

[B. Description of Student Activities 49](#_Toc242693360)

[Unit 1: Materials around Us 49](#_Toc242693361)

[Intended learning outcomes 49](#_Toc242693362)

[Recommended settings and pedagogical approaches 50](#_Toc242693363)

[Materials around us including modern materials and nanomaterials as contents 51](#_Toc242693364)

[Classification as an inquiry-oriented activity 56](#_Toc242693365)

[Predict, Observe, Explain (POE) strategy in science inquiry 59](#_Toc242693366)

[Overview of the Jigsaw method used in the unit 59](#_Toc242693367)

[ICT tools used in the unit 63](#_Toc242693368)

[Hints and tips 63](#_Toc242693369)

[Description of extension activities 63](#_Toc242693370)

[Evaluation tasks for individual activities or individual Units or whole module (including assessment rubrics) 64](#_Toc242693371)

[References to unit 64](#_Toc242693372)

[Unit 2: Activity-Based Site Visit to an Establishment Producing or Using Modern Materials 65](#_Toc242693373)

[Intended Learning Outcomes 65](#_Toc242693374)

[Recommended settings and pedagogical approaches 66](#_Toc242693375)

[Material resources including ICT tools 67](#_Toc242693376)

[Hints and Tips 67](#_Toc242693377)

[Description of Extension Activities 67](#_Toc242693378)

[Evaluation tasks for individual activities or individual Units or whole module (including assessment rubrics) 68](#_Toc242693379)

[C. Description of Extension Activities 69](#_Toc242693380)

[D. Evaluation tasks for individual activities or individual Units or whole module 73](#_Toc242693381)

[Pre-test, post-tests 73](#_Toc242693382)

[Concept maps 75](#_Toc242693383)

[E. Brief Description of Module Design, Development and Validation process 78](#_Toc242693384)

[Theoretical problem analysis 79](#_Toc242693385)

[Design Solution: a prototype module of the site visit 81](#_Toc242693386)

[Empirical problem analysis 82](#_Toc242693387)

[Conclusions based on the Preliminary Study and Implications 84](#_Toc242693388)

[References 85](#_Toc242693389)

[II. Student Activity Sequence Format 87](#_Toc242693390)

[1. Paper and pencil worksheets (default option) 87](#_Toc242693391)

[Student booklet 94](#_Toc242693392)

# A. Teacher’s Guide

## 1. Introduction to the module. The rationale of the module. Relevance of the module in terms of developing an awareness of the role of science in social contexts.

This material science teaching module is developed in the University-school partnerships project for the design and implementation of research-based ICT-enhanced modules on material properties (SAS6-CT-2006-042942-Material Science). The aim of the module is to introduce comprehensive school students basics of materials around us and origins of them. Furthermore, the aim is to give the students a view of occupations or careers in material science and technology branches. The activities have been designed to increase students’ interest towards science and technology.

The aim of the module reflects one widely accepted aim for science education: enhancing scientific literacy of students (e.g., AAAS, 1993; Roberts, 2007). Researchers have tried to define scientific literacy with a few words such as it “stands for what the general public ought to know about science” (Durant, 1993), and it “commonly implies an appreciation of the nature, aims, and the general limitations of science, coupled with some understanding of the more important scientific ideas” (Jenkins, 1994). One useful and rational definition of scientific literacy is included in the PISA document (OECD, 2007). In the PISA framework scientific literacy means the capacity to use scientific knowledge, to identify questions and to draw evidence-based conclusions in order to understand and help making decisions about the natural world and the changes made to it through human activity.

In the beginning of the present millennium there has been an active discussion about public understanding of new materials, like composites, plastics, ceramics and semiconductors, their use and designing. Especially the rapid advancement and growing societal significance of the field of nanomaterials have given rise to demands for enhancing public understanding of these topics (Baird, Nordmann & Schummer, 2004; Sweeney & Seal, 2008).

In addition to scientific literacy issues, another widely discussed challenge in science education is students’ decreasing interest towards science and technology and interest in careers in those fields. These phenomena have been intensively researched since the 1960s. It is known that science in general is quite interesting for students, but most students, especially girls, do not find school science and technology or careers and occupations in those fields interesting (e.g., EU, 2004; 2005).

The rationale of the module is to introduce students to properties and origins of materials around us, to offer a view of careers and occupations in material science related business and industry, and to increase students’ interest to study science. It is believed that new applications of scientific innovations having impact on everyday life can arouse interest in science studies if included in school science curricula.

## 2. Connection of this module to other modules in project *Materials Science*

The aim of this module, *Helping Students to Become Familiar with Materials around Us through Inquiry, Site Visits, and Reading and Writing Activities*, is to engage students in studying properties of materials and to increase their interest to learn (material) science. Within the module the students will become familiar with different materials around us including modern ones like nanomaterials through inquiry, site visits, and reading and writing activities.

In the other modules designed in the MaterialsScience project, the materials are classified and analysed based on their physical properties, like acoustical properties or density. This module guides students to analyse materials around us and to classify them based on their use, properties of the raw materials, and especially based on chemical properties of the materials. Moreover, the students will become familiar with the origins of the materials and with the production of useful artefacts during the site visits.

As it will be shown in the following, this module relates to the other modules but it gives also several new perspectives to the material science. Other specific features include training ICT use and observing safety aspects while working either in classroom or outside school premises.

## 3. Background Information

Assumptions about student learning in the Finnish module include that learning represents each individual learner’s own personal knowledge construction process which presupposes his/her active, goal-oriented and feedback-seeking role (Bransford, Brown, & Cocking, 2000; Bransford & Donovan, 2005). Meaningful learning engages students in tackling the topic to be learnt in such a way that they create meaningful and understandable knowledge structures on the basis of a given topic. The constituents of meaningful learning are the following: activity, intention, contextualization, construction, collaboration, interaction, reflection, and transfer. These serve as development criteria for the module.

*Activity and intention* mean that students take responsibility over their own learning. Thus they set their learning goals and proceed according to the plan to reach the goals. This process may be facilitated, for example, by guiding students to plan in small collaborative groups or by themselves. These challenges to learning are met for example in the planning phase of the site visit. *Reflection* means that students examine their own learning and develop metacognitive skills to guide and regulate their learning. Metacognitive skills are necessary for planning and evaluating one’s own work. For example, self-evaluating or evaluating in a small group, taking multiple-choice tests, doing exercises and consulting answer keys support developing reflective skills. *Collaboration and interaction* mean that students actively take part in group activities and support each other by discussing and sharing knowledge. For example, new contacts and discussions during a site visit give variety to interaction. *Construction and contextualization* mean that students combine their earlier knowledge with the new topics to be learnt and thereby tailor information structures that they can comprehend. Thus learning takes place in real life situations or in situations simulating real-life instances. This in turn presupposes that the learning setting allows for authentic and real-life learning experiences. From the point of view of interestingness, the context in which science ideas are learned, rather than the ideas themselves, has important influence on learning. For instance, when writing a site visit report it is crucial that students write to prospective readers other than the teacher.

The previous characteristics of a learning activity may be realized through a site visit (as already described above) and the use of ICT. For example, by employing the Internet in the planning phase of the visit, students have access to meaningful information about the site to be visited. When looking up information in varied sources, e.g., materials around us or nanomaterials, 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 motivation and interest are enhanced in activities of the module. The concepts “motivation” and “interest” are used here to describe the factors within an individual which arouse, maintain and channel behaviour towards aims of the Material Science Project. A teacher has several possibilities how he or she can help students to develop motivation from outer towards inner or increase student interest in the module activities. Educational research (e.g., Deci, Eghrari, Patrick, & Leone, 1994) give several guidelines to a teacher to solve motivational problems. A teacher can help students to be motivated through choosing of activities and contexts:

* a teacher can support students’ feeling of autonomy by choosing student-centered learning methods like inquiry tasks and other tasks, collaborative learning activities and ICT use and moreover, co-planning of the learning activities;
* a teacher can support students’ social relatedness by choosing inquiry tasks and other tasks, collaborative learning activities, co-planning and ICT use;
* a teacher can support students’ feeling of competency by choosing inquiry tasks and other tasks, collaborative learning activities, co-planning and ICT use and, moreover, choice and use of constructive evaluation methods, like self assessment, portfolio evaluation, informal discussions;
* a teacher can wake up students’ curiosity by choosing surprise-evoking inquiry tasks and other tasks, collaborative learning activities, co-planning and through choosing interesting web pages or simulations;
* a teacher can choose interesting material science content, like new materials, and context, like human being, occupations, technology, or history.

# 4. Pre-requisite Prior Knowledge of Students

There is a lot of research based knowledge about students’ understanding of structure and properties of matter. It is useful to outline what scientific knowledge students should master prior to the course. The students should be familiar with the following conceptual and procedural knowledge. They should

* understand basics of science concepts, principles, and systems appropriate to the grade level:
* know science terminology relevant to materials and properties of materials appropriate to the grade level;
* distinguish between examples and non examples, like iron is metal and plastics are not metals;
* know that structure of matter can be described by a model
* know that properties and behaviour of a material depend on its structure ;
* be able to use basic science process skills appropriate to grade level:
* make observations and measurements;
* develop and use categories to classify observations;
* use reference sources to obtain information (internet, library, data bases, textbook, handbooks, encyclopedias, etc.);
* make estimations and predications based on observations and current knowledge.
* be able to use integrated science process skills appropriate to grade level:
* identify variables and describe relationships between them;
* formulate questions and set aims to the tasks;
* plan field studies, controlled experiments, and other investigations;
* collect and record data using procedures designed to minimize error;
* analyse data and draw warranted inferences.
* have awareness of the social, historical and societal aspects of science:
* know that development of science and technology depends on social and cultural forces;
* know that technological advances have influenced the progress of science and science has influenced developments in technology,
* recognise the personal relevance of science in daily life,
* recognise the interdependence of science, technology, and society.
* recognise the possibility for a career in science and technology related fields;

- be able to use science language and reasoning appropriate to grade level;

- understand basics of the nature of science and technology appropriate to grade level.

Several studies have been organised to find out how students understand structure and properties of matter. For example, Renström, Anderson, and Marton (1990) researched how upper level compulsory school students (13 to 16 years old) conceptualize matter. Based on the data the students understand matter as (a) homogeneous substance, (b) substance units, (c) substance units with "small atoms", (d) aggregate of particles, (e) particle units, or (f) systems of particles. They found also alternative forms of the same conception in some cases. The different conceptions, their varying internal structures, and the alternative forms of conceptions found were logically interrelated in a system, called the "outcome space," which depicts how thinking about matter may vary qualitatively between and within students.

Nakhleh and Samarapungavan (1999) examined elementary school students’ understanding of the particulate nature of matter. This research investigated a wider spectrum of substances by including substances in all three states of matter and by including different types of matter such as granular sugar, solid wood, solid copper wire, liquid water, and a helium-filled balloon. They found that the elementary school students used descriptive rather than explanatory frameworks. In other words, they tended to describe phenomena rather than to explain them. Furthermore, they found that many students had macroparticulate frameworks; that is, they believed matter could be broken down into tiny, even invisible particles by human action. However, they also believed that the smallest particles of a substance such as sugar had all its macroscopic qualities, such as taste and color.

Gable (1998) noted that coordinating macroscopic (observable properties and behavior of substances) and microscopic (atomic and molecular) levels of representation and explanation in chemistry is challenging, even at the college level. McRobbie and associates (Thomas & McRobbie, 2002) also found that secondary school students frequently explain material phenomena at a macroscopic rather than a microscopic level. By eighth grade, students have typically been introduced to the concepts of atoms and molecules that constitute the microscopic level. They have also been taught to explain the states of matter and phase transitions in terms of the microscopic level. However, we have found no comprehensive studies that specifically examine middle school students’ ideas about matter.

Researchers have also studied how students describe properties of artefacts and materials. For example, Krnel, Watson, and Glazar (2005) explored students’ conceptions of the concept of matter by interviewing 84 children aged 3–13 in Slovenia. The patterns of responses indicated that by acting on artefacts and substances students first developed prototypes for substances. This was followed by increasing the use of properties to describe artefacts and substances leading to a growing awareness of the distinction between the intensive properties of matter and the extensive properties of artefacts. Through their actions children gradually develop more elaborated schema that enable them to distinguish between extensive and intensive properties, and hence between artefact and matter (Krenel, Watson, & Glazar, 1998; 2003)

## 5. Aims of the module

The Finnish module of the MaterialsScience1 project is aiming to help 11 – 16 years students to become familiar with materials around us, including nanomaterials, their properties and use. Based on the *Introduction*, *Background* and *Pre-requisite Prior Knowledge of Students* sections, there are challenges to help students to become familiar with new materials, especially nanomaterials. The aim of the Finnish module is to support students to learn about …

* Nature of material science and technology: There is an overlap between material science and technology. Technology is needed in material science research and material science research products new applications, like new materials. There is also strong commercial interest in new materials. Students should also become familiar, how modern ideas and products are created innovatively in authentic environments and how scientific innovations can lead to useful applications.
* Methods of material science and technology: How materials science issues are researched and developed, especially special needs for cleanliness and high technology in research and development. How material science phenomena are researched, simulated and modeled (modeling through simulations) and what reasoning strategies are used there.
* Contents of material science and technology: Physical and chemical properties of materials around us and properties of new materials including nanomaterials. How new materials are produced and where they are used. What properties different materials have and how their behaviour can be explained through analysing the structure of them. How and what classical physics is working − and not working with nanomaterials.
* Careers in material science and technology: Scientists, engineers and many types of jobs in modern MS enterprises and laboratories
* Students’ interest and motivation will be enhanced through studying material science. Activities and learning about useful and new, even exotic materials could awake and satisfy the curiosity of students and increase their feeling of autonomy.

The students will become familiar with materials around us, including nanomaterials, their properties and use through versatile pedagogical approaches. Therefore they will learn also how to acquire information from different sources. The students will learn material science and technology in interaction with nature through scientific experiments. However, there are several situations when it is not possible to learn without written sources of information. Therefore, one aim is that students are able to comprehend scientifically loaded articles as well as yield written documents concerning scientifically meaningful themes. Finally, the students are learning material science and technology outside the classroom during organised site visits. This is an example of a situation where the source of information is outside of the school.

The module is challenging also for the teacher. Especially nanoscience is absolutely a new content for comprehensive school science education. Moreover, pedagogical approaches, like a site visit or concept mapping might be new for a teacher. Therefore, a teacher has also a possibility to learn some new science and new pedagogical approaches.

## 6. Pedagogical approach and context

We introduce here main pedagogical approaches of the module and the context of the module. We start by introducing the context while analysing materials around us. We suggest that the second main pedagogical approach could be that the idea of science inquiry can be used when information is searched in the nature or in printed or digital sources. We present also the Activity-Based Site Visit as a model of demonstrating production and research of materials. The Site Visit Approach is suggested also for studying nanomaterials as these are often nicely demonstrated in science centres and laboratories active in research and development work on modern materials. After these main approaches we discuss how reading and writing activities can be used within all common pedagogical approaches.

Detailed description of pedagogical approaches is given in the publication:

Lavonen, J., Loukomies, A., Meisalo, V., Ampuja, A., Juuti, K., Lampiselkä, J., & Jansson, J. (2009). *Materials around us: Paper, metal and plastics: Teacher guide*. Helsinki: Economic Information Office. Available in the Internet <http://www.mv.helsinki.fi/home/lavonen/material_science_fin.zip>

### 6.1 Materials around us as a context

We understand that there are many ways of classifying materials around us. We give below some illustrative examples without trying to present any comprehensive review.

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

Materials have properties and they can be recognized 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 internal structure must be affected for its chemical properties to be investigated. Chemical properties can be used for building chemical classifications. Examples of chemical properties: reactivity against 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 superveniency 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 it has properties: mass, shape, and temperature. Examples of physical properties of materials are density, resistivity, and thermal conductivity.

### 6.1.1 Paper as a material

Paper is thin material mainly used for writing upon, printing upon or packaging. It is produced by the amalgamation of fibers, typically vegetable fibers composed of cellulose, which are subsequently held together by hydrogen bonding. While the fibers are usually natural in origin, a wide variety of synthetic fibers, such as polypropylene and polyethylene, may be incorporated into paper as a way of imparting desirable physical properties. The most common source of these kinds of fibers is wood pulp from pulpwood trees. Vegetable fiber materials such as cotton, hemp, linen, and rice are also used.

### 6.1.2 Plastics as materials

Plastic is the general term for a wide range of synthetic or semisynthetic polymerization products. They are composed of organic condensation or addition polymers and may contain other substances to improve performance or reduce costs. There are many natural polymers generally considered to be "plastics". Plastics can be formed into artefacts, or films, or fibers. Their name is derived from the malleability, or plasticity, of many of them.

Plastics can be classified in many ways, but most commonly by their polymer backbone (polyvinyl chloride, polyethylene, polymethyl methacrylate, and other acrylics, silicones, polyurethanes, etc.). Other classifications include thermoplastic, thermoset, elastomer, engineering plastic, addition or condensation or polyaddition (depending on the polymerization method used), and glass transition temperature.

### 6.1.3 Ceramics as materials

The word ceramic is derived from the Greek word κεραμικός (keramikos). The term covers inorganic non metallic materials which are formed by the action of heat. Up until the 1950s or so, the most important of these were the traditional clays, made into pottery, bricks, tiles and the like, along with cements and glass. A composite material of ceramic and metal is known as cermet.

Many ceramic materials are hard, porous, and brittle. The study and development of ceramics includes methods to mitigate problems associated with these characteristics, and to accentuate the strengths of the materials as well as to investigate novel applications.

### 6.1.4 Metals as materials

The traditional definition of metal focuses on the bulk properties of metals. They tend to be lustrous, ductile, malleable, and good conductors of electricity, while nonmetals are generally brittle (if solid), lack luster, and are insulators.

Metals have certain characteristic physical properties: they are usually shiny (they have metallic lustre), have a high density, are ductile and malleable, have a high melting point, are hard, are usually solid at room temperature and conduct electricity, heat and sound well. While there are several metals that are low density, soft, and have low melting points, these (the alkali and alkaline earth metals) are extremely reactive, and are rarely encountered in their elemental, metallic form.

Some metals and metal alloys possess high structural strength per unit mass, making them useful materials for carrying large loads or resisting impact damage. Metal alloys can be engineered to have high resistance to shear, torque and deformation. However the same metal can also be vulnerable to fatigue damage through repeated use, or from sudden stress failure when a load capacity is exceeded. The strength and resilience of metals has led to their frequent use in high-rise building and bridge construction, as well as most vehicles, many appliances, tools, pipes, non-illuminated signs and railroad tracks.

**6.1.5 Nanomaterials**

Nanomaterials have become a focal point of materials science due to many superior and unexpected properties that have been discovered by studying materials containing nanoscale structures ("nanoscale” is commonly defined as the interval between 0,1 nm and 100 nm, see e.g., Poole & Owens, 2003; Nalwa, 2004). Since the extent of possible applications and the economic prospects of these novel materials are significant, the research and development of nanomaterials have gained lots of general attention and an explosion of both public and private funding and investments.

During several decades, grain refinement has been an important field of materials science and has proved to be a powerful tool to improve the properties of materials. The research and development of nanostructured materials emerged as a continuation of this in the late 1980’s (Brune et al., 2006). The novel properties that emerge in nanostructured materials cover magnetic, mechanic, electronic, optical, thermodynamic and thermal features as well as the abilities for self assembly and recognition. These properties are size-dependent and have no equivalent in the macroscopic world when they

*“-­ no longer follow classical physical laws but rather are described by quantum*

*mechanical ones;*

*- are dominated by pa­rticular interface effects;*

*- exhibit properties due to a limited number of constituents, since the usual term “material” refers to an almost infinite number of constituents (e.g., atoms, molecules) displaying an averaged statistical behavior.”* (Brune et al., 2006)

One of the most central fields of nanostructured materials has been the development of *high strength materials and composites*. For nanocrystalline metals and alloys, the appealing properties include highly enhanced yield and fracture strength as well as wear resistance, and in some circumstances an improved superplastic formability too. These changes of properties are due to several factors, one of the most important ones being that the traditional dislocation sources, linked to grain boundaries, cease to operate in the nanometer regime. The mechanical properties of nanostructured materials are attractive – e.g., *carbon nanotubes* have tensile strength 10-100 times stronger than the one of steel, and still a very low density – but the fabrication of bulky nanomaterials still remains problematic (Nalwa, 2004; Brune et al., 2006).

The electronic structure of a nanoparticle in the size range between molecule and macroscopic solid is something in between the discrete energy levels of an atom or molecule and the band structure of a bulk material. Consequently, in this intermediate state, matter shows new physical properties originating from the quantization of electronic states. Currently several methods are used in preparing *quantum dots*, that is nanoparticles reflecting the *quantum size effect*. In semiconductor nanoparticles quantum size effects appear chiefly in the optical absorption and emission spectra. It has been thoroughly demonstrated that e.g., the color of a semiconductor becomes size-dependent on the scale of a few nanometers. Regarding metal nanoparticles the scope of interesting quantum size effects is yet larger. Metal nanoparticles can be utilized e.g., in switching and memory elements (Nalwa, 2004; Brune et al., 2006).

In addition to the size-dependent properties that change discontinuously at a certain size, there is also a variety of other effects that happen on the nanoscale and are commonly referred to as nanoscience or nanotechnology. The applications of these *scaling effects* e.g., *field emission applications and nanostructured surfaces* designed to behave in a desired way regarding *wettability* (ultrahydrophobic and self-cleaning surfaces, hydrophilic surfaces), *adhesion* (e.g., towards polymers) and *reflection of light* (antireflective windows, solar cells etc.). Many size-dependent thermodynamical nanoeffects, such as the lowering of the melting point of e.g., gold in the size scale below 20 nm, result simply from the fact that with decreasing particle size the ratio of surface atoms to inner atoms increases (Nalwa, 2004).

Nanoscale materials science encompasses also a number of engineered functions of complex nanomaterials including hybrids, composites, boundary surfaces, molecules and assemblies. For a comprehensive and up-to-date review of current fields of nanoscience and nanotechnology, see Brune et al. (2006).

The public interests, and also the general concerns, are largely focused on the pros and cons of nanotechnology regarding society, environment and health (Macoubrie, 2006; Sweeney, 2006). It is commonly acknowledged that nanomaterials can be employed in favour of the environment. These benefits are expected to rise from e.g. novel types of pollutant filters and more efficient energy production and storage technologies (see e.g., Roco, 2005; Brune et al., 2006). On the other hand, the main risk of nanomaterials concerns the lack of knowledge about the health and environmental impacts of releasing nanoparticles into the environment (Glimell, 2004; Roberts, 2004; Brune et al., 2006).

### 6.2 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." In this chapter, a short description is given what is meant by science inquiry activity in this project.

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 the selected 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 recognize 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 described in this standard. 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.

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

In a science inquiry activity, the students are asked to predict first what will happen. However, it is not fair to ask students to make predictions in the case they do not have any conceptional models on the phenomena. Therefore before the prediction phase the students should be helped to recognise their own experiences and models. For example, classification exercises can help students to recognise their existing models based on their experiences. Writing down the prediction motivates students to want to know the 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 other group members do not initially influence students. (Use Think-Pair-Share, for example, before sharing with the whole group.) Young students may have difficulty explaining their reasoning. Some researchers say that students 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).

In 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, p. xvi).

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

* Learning is an active process, rather than 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 them.
* 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 an 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.
* Preparing the students 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.

### 6.3 Materials science related activity-based site visit

**6.3.1 Historical Background**

The idea of site visits as one pedagogical approach in science teaching is not new, neither in Finland nor in other developed countries. Starting from the early 1970s there was a worldwide effort in the promotion of school-industry links. Many successful case studies were published (see e.g., Bassow, 1984; Kuitunen, 1984; 1985; Kuitunen & Meisalo, 1988), and altogether there was wide publicity for the importance of school science and technology education being related to real technological environments. While the first case studies were mostly of the nature of efforts of individual innovative teachers, there soon emerged a need for more general strategies for the implementation of the idea of productive school-industry links on a more permanent basis.

Subsequently, there emerged a long tradition in Finland, as in many other industrialised countries, of school visits to industry and science centres (e.g., Heureka, Tietomaa, Lusto, Kammi, and Arktikum) or museums (Museum of Technology, Mineral Museum, etc.). Such visits have also been highly recommended in the Framework Curriculum and there has been even an established entrepreneurship education intercurricular issue (NBE, 1994). Organising industrial visits has been the most common method of enterprise (entrepreneurship) education. For example, in 1990, more than 40% of Finnish companies acted as hosts for students and teachers (Erkkila, 1996). Moreover, education for the world of work and technology has been a theme of physics and chemistry promoted by the curriculum of the upper secondary school since 1979. Schools and industry have already for a long time worked together with a model of an industrial visit which is based on the active involvement of students (Sahlberg, 1990; Lavonen & Meisalo, 2007).

Visits are reported to make it easier to discuss cross-curriculum perspectives, awaken and deepen interest in natural sciences and also show how humans apply sciences (cf. Langsford, 2002). Moreover, students experience positive and diverse models for the role of the scientist, or experts and other workers in the industry (Bruce & Bruce, 2000). Furthermore, spokesmen of industry and related interest groups view work experience favourably. According to the training and labour survey by the Finnish Employers' Confederation, nearly half of all the companies, from every branch of industry and every part of the country, are involved in arranging work experience.

Most of the possible visit sites have developed a standard visit program or study materials for several school subjects. This kind of development has happened in many countries (cf. e.g., Nae, Mandler, Hofstein, & Samuel, 1982). Common to all programs and study material is that they guide students to collect information in the visit place and also work with this information. Students can for example do different measurements and chemical analyses during the visit. In science centres and in some industry visit places (like the Physics classroom of ABB and chemistry classroom Gadolin at the University of Helsinki) the study programmes have been designed in such a manner that the student can work with the exhibits and make observations and measurements to study natural laws through experimentation.

In Finland since 1979 'education for the world of work and technology' has been a theme of the physics and chemistry curriculum of the gymnasium (upper secondary school). Schools and industry have worked together with a model of an industrial visit which is based on active involvement of students. We call this model an *Activity-Based Site Visit*. The process of national implementation of this model took quite a long time and it became apparent that this approach necessitates a continuous and ever changing effort. However, the results obtained have been very promising both at a local and also at the national level. Some of our experiences and results are described and analysed below.

**6.3.2 Analysis of the characteristics of the Activity-Based Site Visit**

One of the first tasks of educational research on the industry site visits has been the analysis of the general characteristics of this kind of visit. Two features are of special interest. First, there is the question of educating young people by providing opportunities for contact with industry as well as demonstrating the relationship between school science (physics and chemistry) and industrial processes. On the other hand, arranging a visit is a practical question and already, at the school level, the operation of the scheme is quite complicated. Interesting practical questions arose in connection with the teacher-school and teacher-society relationships. At the municipal level the question is even more complicated. In all cases, the main problems concern relations between people. The model of an industry site visit is not rigid and allows variation within wide limits. For example, visits have been organized in connection with a wide range of school subjects, some projects even emphasizing 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 camp schools. 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.

Activity-Based Site Visits have been found very interesting for schools as they are easy to arrange as curriculum related activities and they are popular among students (e.g., Astin, Fisher, & Taylor, 2002; Griffin, 1998). At least in Finland, science teachers have been most interested in organising visits to science centres and science museums, museums of technology, different kinds of industrial laboratories and production sites, etc. This is also relevant in the discussion on the role of technology in science education (Harrison, 1980; Hodson, 2003). There has been even interest to study learning in informal settings (Anderson, Lucas, & Ginns, 2003; Ramey-Gassert, 1997).

Representatives of industry have been very interested in finding vehicles for discussion between them and schools, too. Their motive has often been the diagnosed need for a large spectrum of skills in the future workforce and influencing career choices of young people (OECD, 2005; Unwin, Fuller, Turbin, & Young, 2004). Several important reasons identified on local and national level include also the public image of the company, good public relations at the local level, and making industrial products and their quality better known to the general public. Actually, even the organisations of industry and other employers have invested in establishing links between them and schools and in gaining publicity in co-operation with educational authorities and media (BBC, 2007; NCW, 2007; United Kingdom. Department of Education and Science, 1981). The interested parties related to materials science include materials researchers, materials producers, materials providers, materials users, etc. They often feel that they have to attract the interest of students as soon as possible. Interest and motivation related problems are important also from the viewpoint of teachers and schools. There has also been extensive research effort on the impact of different factors on career choice (e.g., Lines, McCrone, Schagen, and Benton, 2007; Young, Fraser, & Woolnough, 1997).

**6.3.3 The students' perspective**

The outcomes of an Activity-Based Site Visit from the students' perspective have been evaluated through our own observations, from teachers' questionnaires and by analysing students' reports. Students prepare (often nowadays hypertext) reports analysing what they have learned and what relevant information they have found in the Internet giving feedback to all parties including the experts they have met during the visit as well as their parents. The results of this evaluation present a generally favourable picture. The site visit has been a memorable experience to most students. Factors which contributed to this include the following: the students work in an environment which is new for them and in which there is room for personal initiative and decision-making; opportunities are provided for students to take responsibility for their own work; there is fruitful co-operation within the student groups as well as with experts from the industrial staff, the schoolteacher remaining in the background. The reporting by students on the industrial visit has been assisted by several people outside the classroom. It would seem that the teacher is judged in terms of his success as a provider of such experiences, including fresh human contacts and new feelings, the latter being more important for students in modem society than most science teachers have been prepared to acknowledge in the past.

The acquisition of scientific knowledge, especially on applications of science, has been positive, though this outcome on its own could not justify the use of school time for industrial visits. Probably of more importance is the fact that the relevance of what is learnt at school has become obvious. In this connection, it is important that the industrial visit be organized in a structured manner.

Some students have found summer jobs in the industrial plant they visited and a few have even decided on their future career after finding interesting applications and promising career possibilities in the industry. It is especially important for girls to have direct contact with traditionally male careers. Visits have also contributed to general knowledge of industry as well as to an important aspect of their local environment. It is clear that there are many interrelated factors associated with the pedagogical features of the visits, their goals and the educational outcomes.

**6.3.4 The teacher's role and student activities**

According to the above considerations, the teacher's role in the practical phase of industry site visit should be that of adviser and consultant. However, case studies show that the teacher has to work hard during the preparatory phase also. Knowledge of the national model, or at least of a previous successful study reporting practical experiences, has been essential for the adoption of the idea. In-service courses are able to cover only a small fraction of all teachers, but other information is made available through teachers' journals and personal contacts. The use of Internet and e-mail has grown more and more important over the years. A co-operative attitude on the part of contact persons in industry helps greatly in connection with practical arrangements. It is also better if, at the same, there is teacher-teacher co-operation when there is more than one teacher in the same area planning an industrial visit. In general, almost all teachers who have been involved in industrial visits feel that it has been a very worthwhile experience.

**6.3.5 Viewpoints of industry**

It is important that the viewpoints of industry which might have an effect on the success of the visits be analysed. In several discussions it was noted that the common broad aim for both school and industry was national development. Both parties have their contribution to make, but in the industry site visits these complement each other. Industry obviously would like to change negative public attitudes towards industry and technology in general. It is one of the main reasons why industry is willing to participate in such a project. In a follow-up seminar, the President of the Employers' Federation in Finland stated that 'for industry it is important that enthusiastic, creative and intelligent people come to work within it. Our industry regards it very important that young people at a very early age have personal contact with industry.' Several other important reasons include: (a) the public image of the company; (b) the need for qualified manpower in the future; (c) good public relations at the local level; and (d) making industrial products and their quality better known to the general public.

From the standpoint of a local industry, a site visit has interesting possibilities, but there has also been a strong opinion that visits by schoolchildren to industry have been usually simply a waste of time. In its traditional form, the visit was often a rapid sightseeing tour of the plant followed by distribution of some information, leaflets and the provision of soft drinks to students. The role of staff members who have been working in industry and who have had their own children in the school has been significant in the developments. It is also important that there is adequate information and even tuition available to those persons interested in helping with the arrangements. The feedback from industry and the resources allocated for the purpose have made a most positive contribution to the development of a successful model. One of the identified problems has been the mobility of industrial staff so that too often the expert, who has actively participated in creating a tailored modification of the standard visit model, has soon been transferred to somewhere else and a new person has had to be recruited and trained. Sometimes the school alumni associations or parents’ unions have helped in finding experts who have common interests with schools.

**6.3.6 Recommended settings and pedagogical approaches***:*

The teacher has the overall responsibility for organising the visit, contacting parents, finding necessary resources, considering all safety precautions etc. However, one of the key features of the successful Finnish model has been the strong involvement of participating students at all stages of organising a visit. The activities begin with co-operative planning (including all aspects from choosing an interesting site to fund-raising) and finding advance information 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.

The Finnish model presented below is based originally on the study of Kuitunen and Meisalo (1988) but it is updated and modified to better fit the European scene. Some alternative approaches with more detailed forms etc. can be found e.g. in the following Internet links: Building industry <http://www.ncw.org.uk/images/docs/SiteVisit_Arrangements.pdf>, School TV [www.bbc.co.uk/print/northernireland/schools/11\_16/gogetit/teachers/visit.shtml](http://www.bbc.co.uk/print/northernireland/schools/11_16/gogetit/teachers/visit.shtml).

In the Finnish Activity-Based Site Visit model there are the following stages:

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

* preliminary planning on general level by a group of physics and chemistry teachers and a student councellor,
* choosing the site to be visited.
* informing the school management team on the plans to organise a visit to get a 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 the student skills and abilities)

3. The 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.
* planning of the tasks and a way of reporting (preliminary questions to the plant, structure of the report, ICT use in reporting, evaluation of the visit and the report),
* co-planning of the visit,
* groups prepare their project plans (goals, tasks, reporting plan),
* students learn about the industrial branch and the plant using Web resources etc.,
* preparation and sending of the questions (which are interesting for students) to the site contacts,
* briefing of students for(?) 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 to be given to all involved, including
  + the participating students
  + accompanying teachers
  + non-teacher supervisors
  + any staff at the site to be visited who will receive/work with the students
* 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.
* You must also ensure that everyone involved is aware of
  + contingency plans for unforeseen circumstances
  + first-aid facilities
  + emergency telephone numbers.
* Members of the school office staff should be notified in writing of the dates and times of all visits and the students and teachers involved.

5. The site visit (2 – 4 hours):

* introduction (plant, what they are doing, what kind of people are working there),
* “sightseeing” around the plant,
* group work,
* different topics as agreed with students,

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

* students prepare the reports,
* 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.

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 is 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 students’ behaviour
* if the site-visit will be organized 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 on 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’d like to have industrial visits in 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 in 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.

### 6.4 Activities supporting reading and writing

**6.4.1 Introduction**

We present in this chapter some activities supporting reading and writing. These activities can be used within most pedagogical approaches including science inquiry and site visit.

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, mindmaps and 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 practice 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 the 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.

**6.4.2 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 heavily relies on developing metacognitive skills. This 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 teaching 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 about 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. This way the active reader optimally manages 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. She orders the contents by, for instance, recognising, classifying, comparing, and evaluating new information. In addition, she redefines the questions posed in the beginning and evaluates her work.

*3. Connecting previous knowledge with new information*After reading the active reader combines her 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 points that students have not understood. The questions can be collected on a white board or on a transparency for everybody to reflect. While reading, students can create a mind map on the basis of the text. This mind map serves as a visual representation on 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 read. 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 recognize the relationship between the main ideas and their expansion  
  - to infer from the text – read between the lines  
  - to draw conclusions  
  - to recognize the writer’s purpose.
* Create a mindmap 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 mindmap 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 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 mindmap on the read text and presents it to the rest of the group. The created mindmaps 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, mindmaps and preplanning tools serve as frames.

**6.4.3 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,
* organizing 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 bulleted 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 transforming writing tasks at school into pleasant experiences:

* Writing will not feel like taking a test for as long as the atmosphere in class is such that it is easy to ask help from the teacher and class mates.
* 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 to create a more concise introduction?, How to emphasise the key concepts more?.*
* Students are guided to discuss the topics of their essays because talking (thinking out loud) aids understanding.
* Students are encouraged to structure the topic of an essay or an answer by creating a mindmap or specifying questions.
* Writing is given a purpose, in other words, the prospective readers are other than the teacher.
* There will be no rigid timeline for writing which 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 mindmapping and organising information.
* Writing is integrated with using 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?
* Shouldn’t I try to explain some concepts?
* Shouldn’t 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 which help in managing writing more easily than when dealing with enormous units of information. Linna (1994, 35) lists the phases of process 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, mindmaps) 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 mindmapping. 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 from their language classes of process writing, 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.

**6.4.4 Activities focusing on reading and writing**

This chapter deals with activities which can be used within Finnish MaterialsScience module that emphasise 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 fulfill 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 recycling materials. Why and how materials should 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, at the street or at home to find out how people feel about recycling. Use an MP3 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 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 homesites 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 in 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 on 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, divide the students into groups and 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.”*

## 7. Relevant ICT tools

In the Finnish MaterialsScience module students activities start typically by a search on relevant information over the Internet. Contact with the expert on site in advance of a visit is taken by e-mail. Concept maps are drawn and analysed using CmapTools. Microcomputer-Based Laboratory facilities are used during the visit and afterwards at school to analyse material properties as well as the feedback data. Moreover, students will use basic tool applications in several ways. Therefore, it is useful to shortly analyse use of ICT in our project.

ICT use is appropriate to classify from the point of view of Finnish material science module into *tool applications (use of tool software)* and *ICT use in learning (learning through ICT)* (Webb, 2002; Lavonen, Juuti, Aksela, & Meisalo, 2006). In the *tool category*, ICT is treated as a set of available software enabling students to accomplish their tasks in an effective way. To this category belongs for example the use of word processing and spreadsheets in science learning activities. A teacher can use a PowerPoint presentation when he or she explains a science model.

*ICT is used in learning* in three different ways in Finnish material science module: computer-assisted inquiry, modeling and communicating with ICT. *Computer-assisted inquiry* is the use of ICT as an aid in collecting information and data from various sources, like Internet, to support scientific reasoning. Typically ICT is used as an agent for interaction with the information source (nature or written source), like the Internet or a Microcomputer-Based (school) Laboratory (MBL).

Previous classification was done from the point of view of ICT use – not from the point of view of a single software or ICT tool (look a description of ICT tools in science education by Denby & Campbell, 2005). For example, equipment and software in Microcomputer-Based (school) Laboratories (MBLs) can be used as tools and also in a Computer-assisted inquiry project. In the tool category MBL is a tool for data capture, processing and interpretation.

### 7.1 Tool applications

In material science learning, students will use different tool applications and also learn what needs are met by these application and when and how to use their different features. Word processing software can be used, for example, for organising ideas and writing project reports. Spreadsheet can be used, for example, for analysing data and modelling. To select the right tool application it is important to understand what types of thinking, learning experiences, and experiences of ICT use each ICT tool supports.

*Reading and writing* represent well-established approaches to studying and learning sciences. However, studying that centres on reading and writing faces new challenges when learners look up information on the Internet and use word processing. For instance, reading may entail copying web-based information on the notepad and writing in turn 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. Learning presupposes processing the available information by, for instance, reading and writing. In addition, mindmaps and knowledge structuring serve as effective means to process information (Bentley & Watts, 1989). In fact, by processing information learners acquire the (thinking) skills necessary for autonomous information processing. Moreover, when processing information in small groups, learners practice collaboration and communication skills as well. Mastery of these skills is a pre-requisite for professionals serving in various fields of expertise. Students may be encouraged and inspired to read and write by using information and communication technology and by choosing an appropriate teaching method. By employing the Internet, students have access to meaningful information by consulting, for example, electronic books, hypertexts and hypermedia in the 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. (Lavonen, Juuti, & Meisalo, 2007)

Referring to Bransford, Brown, and Cocking (2000, 31) a person who has developed an expertise in a particular area of knowledge is able to think effectively about problems in that area. Therefore, a teacher should help students to develop expertise. Bransford et al. (2000, 9) suggests that experts’ abilities to think and solve problems owes to a rich body of knowledge about subject matter. Furthermore, Bransford et al. (2000, 36-37) have argued that content knowledge of experts in physics is organised around core concepts or “big ideas” that guide their thinking about their domains. Learning activities that help students to create a network of concepts seem to be advantageous to learning (Trowbridge & Wandersee, 1989, 117). *Network representations* are two dimensional, hierarchical node-link representations that depict the major concepts found in domain knowledge. The concepts are linked by lines and those links are labeled with connecting words that explain the nature of link. Network representations in certain domains of science are similar to concept maps, introduced by Novak (Mintzes & Wandersee, 1989, 69; Trowbridge & Wandersee, 1989, 115-123). *Mind maps* are closely related to concept maps. In mind maps related ideas radiate out from the one central idea. Mind mapping is a useful tool for students to share prior knowledge, to establish connections between ideas and to list ideas quickly without judgment. Concept and mind mapping tools support the developing of diagrams in which teachers or students illustrate concepts and the relationships between them. CmapTools is free software suitable for making concept maps and mind maps. It can be downloaded from the website of IHMC, A University Affiliated Research Institute of the University of West Florida http://cmap.ihmc.us/download/. More information about the product, including examples of its use can be found on the website at http://cmap.ihmc.us/

### 7.2 Computer-assisted inquiry

Computer-assisted inquiry is the use of ICT as an aid to collect information and data from various sources. For example, MBL tools can be used in science inquiry having nature as a source of information. MBL can help in data acquisition and data processing in laboratory. Science inquiry is of course essentially similar with or without using MBL tools. Another example of computer-assisted inquiry is an inquiry where internet or a Web Based Learning Environment (WBLE) is used as a source of information. In both cases it is important that also a student - not only a computer – is processing acquired information so that he or she learn new knowledge and become familiar with the principles of scientific reasoning (cf. Millar, 1996, p. 15). An overview of science inquiry is presented in the next chapter.

### 7.3 Using ICT in modeling

In science education literature *models and modelling* are connected to learning. By a model is meant “a representation of an idea, artefact, event, process, or system”. The purpose of any model in science is to simplify a phenomenon and to make an explanation of it. Consequently, models have several tasks in science education: they help student to learn sciences, to learn about science, the history of science and methodology and, moreover, to learn to do science. (Gilbert & Boulter, 2000). One essential purpose of science education is to help students to gain an understanding of basics of science models or knowledge as is appropriate to their needs, interests and capacities. Rogers (2006) analysed use of simulations and modelling software in science education. He claims that science teachers have embraced the use of simulation software more enthusiastically than modelling software. Some simulations are visual aids, chosen for their ability to help students visualise complex or abstract phenomena. Others feature virtual experiments which allow students to perform pseudo-laboratory activities and obtain quasi-experimental data. In both cases it is common for the software to facilitate activities which support the development of valuable skills for scientific investigation. However, Rogers (2006) argued that modelling software has even greater potential for developing these skills towards a deeper level of scientific understanding. However, many modelling software, like Stella, developed for dynamic modelling, appear to be less accessible than graphically-rich simulations.

Simulations like Java applets/physlets are widely used in science education. Simulations are available commercially, but many can also be found in the web-pages (see e.g., Christian & Belloni, 2001). An applet is a software component that runs in the context of another program, for example a web browser. Applets are most often used ICT applications in the explanation or interpretation of processes in nature or in technological environments (McFarlane & Sakellariou, 2002). For example, in the web page of the University of California (http://www.chem.uci.edu/undergrad/applets/) there is a nice collection of applets that give students a chance to explore some scientific principles which simulate the way a professional chemist works. A similar collection of physics applets can be found in the web pages of University of Oregon (http://jersey.uoregon.edu/vlab/).

### 7.4 Communicating with ICT

Electronic mail, newsgroups, chat rooms, and videoconferencing can be used for educational purposes (Madjidi & Hughes, 1999). They offer possibilities for learning and even electronic brainstorming and other forms of processes where social interaction is emphasized.

Email and mailing lists are the most popular Computer Mediated Communication (CMC) tools, used to exchange messages between individuals. A newsgroup allows users to read and contribute to special-interest 'newsgroups'. Computer conferencing (discussion board) enables groups of people to hold discussions by reading and posting text messages on a computer system. The advantages over mailing lists are that the messages are archived and the structure of the discussion is also recorded. Computer conferencing is widely used to support learning. Internet Relay Chat (IRC) allows users to chat 'live' (in real time) using text or audio. MSN messenger and Skype are nowadays well known sophisticated chat tools. Through videoconferencing geographically distant people can hold discussions in real time, during which they are able to hear and see each other and share various other types of data. All previously mentioned CMC-tools can be used in several ways in science education. For example, students from the same school or from different schools can work and communicate together towards common goals in their project. It is also possible that older students supervise younger students’ projects through CMC tools. Students can contact experts in universities or industry through CMC tools.

Learning Management Systems, LMSs, like Moodle, allow a combination of versatile CMC tools for organising course materials and establishing whole science courses. A material science course in a LMS can consist of a number of lessons and activities. A lesson can consist of simulations, videos, web pages and web lectures. After each lesson there can be assignments which are returned to the LMS. After the lesson there can be also group discussion or a group activity in a special workspace in the LMS. In countries where there are small schools and few students per a school, neighbour schools can have a common course in the LMS and students in separate schools can join the common course.

Science teachers are showing growing interest in the previously described variation of Web-Based Learning (WBL). Lectures notes, homework assignments, online books, and complete courses in science topics, can now be found on the Web (Berenfeld, 1996; Berge & Collins, 1998).Web-Based Learning Environments (WBLEs) offer inspiring possibilities in science teaching. Online discussions and information distribution via WBLE bring the opportunity for students to learn from one another through exercises when jointly treating the topics to be learned, evaluating information, and learning new things. However, ICT in itself does not alone ensure although it may help students to learn. Promoting learning by providing support to the learning process is essential to teaching. Teaching in WBLE emphasises study guidance more than ever: teachers and students may not meet in the course of the learning process, and students are expected to work more independently. Interaction in WBLE differs from that in contact teaching, presenting challenges to the teacher in charge of guidance. Well-designed teaching and educational solutions that help to achieve the learning objectives enable ICT to be used successfully to support learning and teaching. In practice, WBLEs are often used to refer to a combination of face-to-face and online learning. (Brooks, Nolan, & Gallagher, 2001)

## 8. Common student difficulties

The difficulties students can face in their learning activities are already discussed above. For example, typical students’ conceptions dealing with the Finnish module are presented in Chapter *4” Pre-requisite Prior Knowledge of Students*”. Difficulties in science inquiry, site visit and reading and writing activities are presented and discussed in Chapter *6 “Pedagogical approach and context*”. Finally student difficulties with ICT use is presented in Chapter 7*”ICT Use in the Finnish Material Science Module*”.

## 9. Monitoring Student Learning:

Monitoring of student learning or assessments can be done in many different ways. Besides conventional paper and pencil tests, assessment should cover evaluation of performances, project reports, concept maps or other documents.

An important purpose of assessment is tutoring the student improvement during the unit. This kind of assessment is for formative purposes and it will allow skills to be noted, reflected on and developed in a continuous manner. Summative assessment is organised at the end of a unit and it is designed based on the intended learning outcomes of the unit.

### 9.1 Instruments for the assessment of learning outcomes

Instruments for assessment of learning outcomes are presented in the end of each unit. These instruments are for summative purposes.

### 9.2 Monitoring student engagement and motivation

Instruments for measuring students’ engagement and motivation are presented in the separate package: ”Measuring Students’ Motivation on Learning MaterialsScience Modules”.

Examples of the evaluation tools are described in the section D.

## 10 Rationale of Extension Activities

Most of the activities can be enlarged through choosing an appropriate activity emphasising reading and writing, described in Chapter *6.3 “Activities Supporting Reading and Writing*”. For example, students can produce a booklet introducing a plastics industry branch using Internet resources.

## 11 Other Useful information – List of Relevant Articles, Links to Web Sites

Testing materials:

http://www.bbc.co.uk/schools/ks2bitesize/science/activities/characteristics\_material.swf

Recycling: http://www.sciencenetlinks.com/lessons.cfm?BenchmarkID=8&DocID=386

## 12 References

AAAS (1993). *(American Association for the Advancement of Science). Benchmarks for science literacy.* New York: Oxford University Press.

American Association for the Advancement of Science [AAAS] (1989), *Project 2061 - Science for All Americans*, AAAS, Washington, DC.

Anderson, D., Lucas, K., and Ginns, I. (2003). Theoretical perspectives on learning in an informal setting. *Journal of Research in Science Teaching 40*(2), 177-199.

Anderson, R.D (2007) Inquiry as an Organizing Theme for Science Curricula. In S:K: Abell & N.G. Lederman (Eds.), Handbook of Research on Science Education. London: Lawrence Erlbaum Associatiates, Publishers, 807-830.

Astin, C., Fisher, N,, and Taylor, B. (2002). Finding physics in the real world: how to teach physics effectively with visits. *Physics Education 37*(1),18-24.

Baird, D., Nordmann, A., & Schummer, J., (Eds.) (2004). *Discovering the Nanoscale*. Amsterdam: IOS Press.

Baker, L. (1991). Metacognition, Reading and Science Education. In C.M. Santa & D.E. Alvermann. *Science Learning: Processes and Applications*. Newark: International Reading Association, IRA.

Bassow, H. (1984). Bridging the Industry-High School Gap. *Journal of Chemical Education,. 61*, (4), 367.

BBC (2007). Teachers: campus/industrial visit. Available at [www.bbc.co.uk/print/northernireland/schools/11\_16/gogetit/teachers/visit.shtml](http://www.bbc.co.uk/print/northernireland/schools/11_16/gogetit/teachers/visit.shtml) (Visited 16.08.2007).

Bennett, J., Hogarth, S., & Lubben, F. (2003). *A systematic review of the effects of context-based and Science-Technology-Society (STS) approaches in the teaching of secondary science*. Version 1.1 In: Research Evidence in Education Library. London: EPPI-Centre, Social Science Research Unit, Institute of Education.

Bentley, D. & Watts, M. (1989). *Learning and teaching in school science: Practical alternatives*. Milton Keynes: Open University Press.

Berenfeld, B. (1996). Linking students to the infosphere. *T.H.E. Journal 4*(96), 76-83.

Berge, Z.L. & Collins, M. (Eds.) (1998). *Wired together: The online classroom in K-12*. Hampton Press, Cresskill, NJ.

Berlyne, D.E. (1965). Curiosity and education. In J.D. Krumboltz (Ed.), *Learning and the educational process* (pp. 67-89). Chicago: Rand McNally.

Brooks, D.W., Nolan, D.E., & Gallagher, S.M. (2001). Web-teaching: *A Guide to Designing Interactive Teaching for the World Wide Web* (2nd ed.) New York: Kluwer Academic & Plenum Publishers.

Bransford, J.D. & Donovan, S.M. (2005). *How Students Learn Science in the Classroom*. Washington, D.C.: National Academies Press.

Bransford, J.D., Brown, A.L., & Cocking, R.C. (Eds.) (2000). *How People learn: Brain, Mind, Experience, and School*. Washington, D.C.: National Academy Press.

Bruce, S. P. & Bruce, B. C. (2000). Constructing images of science: people, technologies, and practices. Computers in Human Behavior, 16(3), 241-256.

Brune, H., Ernst, H., Grunwald, A., et al. (2006). *Nanotechnology. Assessment and Perspectives.* Berlin Heidelberg: Springer.

Christian, W. & Belloni, M. (2001) *Physlets: Teaching Physics with Interactive Curricular Material*. New York: Prentice Hall.

DeBoer, G. E. (1991). *A history of ideas in science education*. New York: Teachers College Press.

Deci, E. L., Eghrari, H., Patrick, B. C., & Leone, D. (1994). Facilitating internalization: The self-determination theory perspective. *Journal of Personality, 62*, 119-142.

Denby, D. & Campbell, B. (2005). *ICT in support of science education: A Practical User’s Guide*. York: York Publishing Services Ltd, The University of York Science Education Group.

Durant, J.R. (1993), "What is scientific literacy?" in *Science and culture in Europe*, eds. J.R. Durant & J. Gregory, Science Museum, London, pp. 129-137.

Erkkila, K. 1996. Enterprise Education in the Case of Finland. Paper presented at the World Congress of Comparative Education Societies (9th, Sydney, Australia, July 1996).

EU (2004). Europe needs more scientists! Brussels: European Commission, Directorate-General for Research, High Level Group on Human Resources for Science and Technology in Europe. Available at: [www.tekes.fi/EU/fin/6po/tutkijaliikkuvuus/gago\_report\_final\_en.pdf](http://www.tekes.fi/EU/fin/6po/tutkijaliikkuvuus/gago_report_final_en.pdf)www.tekes.fi/EU/fin/6po/tutkijaliikkuvuus/gago\_report\_final\_en.pdf [Visited 7.11.2007].

EU (2005). Europeans, science and technology. Eurobarometer 224. Brussels: The Directorate General Press and Communication of the European Commission. Available from: http://ec.europa.eu/public\_opinion/archives/ebs/ebs\_224\_report\_en.pdf [Visited 7.11.2007]

Gabel, D. (1998). Complexity of chemistry and implications for teaching. In B.J. Fraser & K. Tobin (Eds.), *International handbook of science education research.* Dordrecht, The Netherlands: Kluwer.

Glimell, H. (2004). Grand Visions and Lilliput Politics: Staging the Exploration of the ´Endless Frontier´. In D. Baird, A. Nordmann, & J. Schummer (Eds.), *Discovering the Nanoscale* Amsterdam: IOS Press.

Gilbert, J.K. & Boulter, C.J. (eds.) (2000). *Developing Models in Science Education*. Kluwer Academic Publishers.

Griffin, J. (1998). Learning science through practical experiences in museums. *International Journal of Science Education, 20*, 655-663.

White, R.T. & Gunstone, R.F. (1992). *Probing Understanding*. London: Falmer Press.

Harrison, G. (1980).The Role of Technology in Science Education. In: C. McFadden (Ed.), *World Trends in Science Education*, pp. 18-26. Halifax, Nova Scotia, Atlantic Institute of Education.

Hodson, D. (2003). Time for action: Science education for an alternative future. *International Journal of Science Education, 25*, 645–670.

Jenkins, E.W. (1994), "Scientific literacy" in *The international encyclopedia of education (Vol. 9)*, Eds. T. Husen & T.N. Postlethwaite, 2.th edn, Oxford, UK: Pergamon Press, 5345-5350.

Krnel, D., Watson, R., & Glazar, S.A. (1998). Survey of research related to the development of the concept of ‘matter’. *International Journal of Science Education, 20*(3), 257–289.

Krnel, D., Watson, R., & Glazar, S.A. (2003). The Development of the Concept of ‘Matter’: A Cross-age Study of How Children Classify Materials. *Science Education, 87*, 621–639

Krnel, D., Watson, R., & Glazar, S.A. (2005). The Development of the concept of ‘matter’: a cross-age study of how children describe materials. *International Journal of Science Education, 27*(3), 367–383.

Kuitunen, H. & Meisalo, V. (1988). Science and technology education and industry. In C. Layton (Ed.), *Innovations in science and technology education 2*. Paris: UNESCO, 141-154.

Kuitunen, H. (1984). Visit to Industry, Based on the Students' Own Activity, and its Diffusion in the Senior Secondary School in Finland. (Paper presented at the Third International Symposium on World Treads in Science and Technology Education, Brisbane, Australia, December 1984.)

Kuitunen, H. (1985). A Visit to a Factory as a Part of Physics and Chemistry Education and its Learning Outcomes in the Senior Secondary School in Finland. Proceedings of Nordic Conference of Science and Technology Education, Karslunde Strand, Denmark, pp. 8-12.

Langsford, S. (2002). Museums as resources for science teaching. *Australian Primary & Junior Science Journal, 18*(1), 17-19.

Lavonen, J., Juuti, K., & Meisalo, V. (2007). Reading and Writing Facilitating ICT Use in School Science. In V. Uskov (Ed.), *Proceedings of the 10th IASTED International Conference on Computers and Advanced Technology in Education ~CATE 2007, Beijing, China ~ Globalization of Education Through Advanced Technology, October 8 – 10, 2007*. Anaheim: ACTA Press, 447 – 452.

Lavonen, J., Meisalo, V. (2007). Ekskursio koulun työtapana. Toiminnallinen opintokäynti. Available at <http://www.edu.helsinki.fi/malu/kirjasto/yto/ekskursio/index.htm> (Visited 16.08.2007)

Lavonen, J., Juuti, K., & Meisalo, V. (2007). Reading and Writing Facilitating ICT Use in School Science. In V. Uskov (Ed.), *Proceedings of the 10th IASTED International Conference on Computers and Advanced Technology in Education ~CATE 2007, Beijing, China ~ Globalization of Education Through Advanced Technology, October 8 – 10, 2007*. Anaheim: ACTA Press, 447 – 452.

Lines, A., McCrone, T., Schagen, S., and Benton, T. (2007). Year 9 career choices - underpinning research for development of a career portal for the 11-19 age group. Available at [www.nfer.ac.uk/research-areas/pims-data/outlines/year-9-career-choices-underpinning-research-for-development-of-a-career-portal-for-the-11-19-age-group.cfm](http://www.nfer.ac.uk/research-areas/pims-data/outlines/year-9-career-choices-underpinning-research-for-development-of-a-career-portal-for-the-11-19-age-group.cfm) (Visited 16.08.2007).

Linn, M.C., Davis, E.A., & Bell, P., Eds. (2004). *Internet Environments for Science Education.* Mahwah, New Jersey, Lawrence Erlbaum Associates.

Linna, H. (1994). *Prosessikirjoittaminen: Kirjoittamisen suuri seikkailu*. [Process writing: writing as an adventure]. Porvoo: WSOY, Opetus 2000.

Macoubrie, J. (2006). Nanotechnology: public concerns, reasoning and trust in government. *Public understanding of science, 15*(2), 221-241.

Madjidi, F., Hughes, H. W., Johnson, R.N., & Cary, K. (1999). *Virtual Learning Environments.* ERIC ED429565.

McFarlane, A. & Sakellariou, S. (2002). The Role of ICT in Science Education, *Cambridge Journal of Education*, 32(2), pp. 221-232.

Millar, R. (1996). Towards a science curriculum for public understanding, *School Science Review*, 77(280), 7-18.

Mintzes, J.J. & Wandersee, J.H. (1989). Research in Science Teaching and Learning: A Human Constructivistic View. In J.J Mintzes, J.H Wandersee, and J.D.Novak (Eds.) Teaching Science for Understanding: A Human Constructivistic View. San Diego: Academic Press, 82 – 83.

Nae, H., Mandler., V., Hofstein, A., & Samuel, D. (1982). Chemistry in Action. How to Plan a Visit to the Chemical Industry. *Journal of Chemical Education* *59,* (7), 582-3.

Nakhleh, M.B. & Samarapungavan, A. (1999). Elementary school children’s beliefs about matter. *Journal of Research in Science Teaching*, 36, 777–805.

Nalwa, H.S. (Ed.) (2004). *Encyclopedia of Nanoscience and Nanotechnology.* American Scientific Publishers.

NBE (1994) *National Framework Curriculum for Basic Education 1994.* Helsinki: Finnish National Board of Education.

NCW (2007) National construction week. Site visits. Available at [www.ncw.org.uk/info/sitevisit\_introduction.cfm](http://www.ncw.org.uk/info/sitevisit_introduction.cfm) (Visited 16.08.2007).

OECD (2007). PISA 2006. Science Competencies for Tomorrow’s World: Volume 1 – Analysis. Paris: OECD.

OECD Global Science Forum. (2005). Papers presented in the conference *Declining enrolment in science and technology* in November 2005. Available at: http://www.caos.nl/ocw/programme.html <http://www.caos.nl/ocw/programme.html> (Visited 15.2.2007).

Palmer, D. (1995). The POE in the primary school: An evaluation. *Research in Science Education, 25*(3), 323-332.

Poole, C.P. & Owens, F.J. (2003). *Introduction to Nanotechnology.* Hoboken, NJ: John Wiley.

Ramey-Gassert, L. (1997). Learning science beyond the classroom. *The Elementary School Journal, 97*, 433-450.

Renstrom, L., Anderson, B. & Marton, F. (1990). Students’ conception of matter. *Journal of Educational Psychology, 47*(2), 154–156.

Rivard, L.P. (1994). A Review of Writing to Learn in Science: Implications for Practice and Research. *Journal of Research in Science Teaching, 31* , 969-983.

Roberts, J.A. (2004). Deciding the Future of Nanotechnologies: Legal Perspectives on Issues of Democracy and Technology. In D. Baird, A. Nordmann & J. Schummer (Eds.), *Discovering the Nanoscale*Amsterdam: IOS Press.

Roberts, D.A. (2007). Scientific literacy/Science literacy. In S.K. Abell & N.G. Lederman (Eds.), *Handbook of research on science education* (pp. 729-780). Mahwah, NJ: Lawrence Erlbaum Associates.

Roco, M., (2005). Societal implications of nanoscience and nanotechnology: Maximizing human benefit. *Journal of nanoparticle research,* [Online], *7*(1), 1.

Rogers, L. (2006). Motivating teachers and pupils to engage with modeling. Paper presented at the GIREP Conference, August 20 – 25, 2006, Amsterdam, Netherlands.

Sahlberg, P. (Ed.) (1990) Luonnontieteiden opetuksen työtapoja. Toiminnallinen teollisuusvierailu. Helsinki: Valtion painatuskeskus, Kouluhallitus, FINISTE, 221-229.

Sweeney, A., (2006). Social and ethical dimensions of nanoscale science and engineering research. *Science and engineering ethics,* [Online], *12*(3), 435.

Sweeney, A.E. & Seal, S. (Eds.) (2008). *Nanoscale Science and Engineering Education.* Valencia, CA: American Scientific Publishers

Thomas, G.P. & McRobbie, C.J. (2002). Collaborating to enhance student reasoning: Frances’ account of her reflections while teaching chemical equilibrium. *International Journal of Science Education*, *24*, 405–423.

Trowbridge, J.E., & Wandersee, J.H. (1989). Theory-Driven Graphical Organizers. In J.J. Mintzes, J.H. Wandersee & J.D. Novak (Eds.), Teaching Science for Understanding: A Human Constructivistic View. San Diego: Academic Press, 117.

Tynjälä, P. (1999). Towards Expert Knowledge? A Comparison Between a Constructivist and a Traditional Learning Environment in University. *International Journal of Educational Research 31* (5).

United Kingdom. Department of Education and Science (1981). Schools and Working life. Some Initiatives. London, HMSO,

Unwin, L., Fuller, A., Turbin, J. & Young, M. (2004). What Determines the Impact of Vocational *Qualifications? A Literature Review*. Research Report No 522, Centre for Labour Market Studies, University of Leicester. Available at: http://www.dfes.gov.uk/research/data/uploadfiles/RR522.doc [Visited 20.1.2007].

Webb, M. (2002) Pedagogical reasoning: Issues and solutions for the Teaching and learning of ICT in Secondary School, *Education and Information Technologies* *7*(3), pp. 237-255.

White, R.V. & Arndt, V. (1991). *Process Writing*. London: Longman.

Young, D.J., Fraser, B.J. & Woolnough, B.E. 1997. Factors affecting student career choice in science: An Australian study of rural and urban schools. *Journal of Research in Science Education , 27*(2), 195-214.

# B. Description of Student Activities

Detailed descriptions of Pedagogical approaches are given in the publication:

Loukomies, A. Lavonen, J., Juuti, K., Lampiselkä, J., M eisalo, V., Ampuja, A. & Jansson, J. (2009). *Materials around us: Paper, metal and plastics: Teacher guide*. Helsinki: Economic Information Office. Available in the Internet <http://www.mv.helsinki.fi/home/lavonen/material_science_fin.zip> (Visited 1.10.09)

## Unit 1: Materials around Us

**Subject area**: Physics, Chemistry, Biology

**Grade level**: Grades 5 - 8 / age 10 - 14

**Anticipated teaching time**: 2 – 6 hours

### Intended learning outcomes

The main intent is that students will learn within the classification activities and activities where concept maps are used for learning basics of the materials around us. Especially, the students should learn how the materials can be classified based on their properties. These classifications serve also as abasis for the recognition of the materials and learning the meaning of the concepts. For example meaning for a concept “metal” is created through analysing artefacts which are made of metals and non-metals, like plastics. The comparisons and classifications help students to recognise the properties of a metal and create meaning for the concept. Moreover the students should learn about the use of materials in manufacturing and about production of artefacts. Finally the students should learn about use of the materials and artefacts, made of materials, in everyday life. For learning the previous issues the students are making science inquiries (practical work) and concept maps.

In detail the students will

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

* know name of basic materials and terminology used in describing them;
* understand meaning of 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;
* 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:

* make observations and measurements;
* develop and use categories to classify observations;
* use reference sources to obtain information (internet, textbook, handbooks, etc.);
* make estimations and predications based on observations and current knowledge.

3. Use integrated science process skills appropriate to grade level:

* identify variables and describe relationships between them;
* formulate questions and set aims to the tasks;
* collect and record data;
* analyse data and draw warranted inferences;
* make concept maps.

4. Increase motivation and interests:

* maintain a sense of curiosity about natural phenomena;
* maintain interest toward 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 properties of them;
* understand how technological advances have influenced the progress of science and how science has influenced developments in technology;
* recognize the personal relevance of science and technology in daily life;
* respect the contributions of science and technology to the quality of human life;
* recognize the interdependence of science, technology, and society.

6. Communicate effectively using science language and reasoning:

* use the language and concepts of science as a means of thinking and communicating;
* prepare written and oral reports describing the findings of investigations and the reasoning which led to the conclusions;
* report results honestly;

7. Understand the nature of science and technology:

* understand that science is an inquiry process used by humans to construct knowledge based upon observable evidence;
* understand that technology is a discovery process used by humans to design usable artefacts based on creative process;
* distinguish between science and technology;
* recognise the vital need for creative thinking and imagination in designing and conducting scientific inquiries and technological processes.

### Recommended settings and pedagogical approaches

There are three main pedagogical approaches in the module. Students are learning about materials and their properties by classification activities (next chapter). They are learning production of artefacts and properties of them through concept mapping (Chapter 7.1).They learn properties of materials also through science inquiry activities (Chapter 6.3).

### Materials around us as contents

**Put here from the booklet:**

Materials around us:

Metals, plastics and paper



Pages 4-7, 12-15, 18-21, 24-27

The text and figures are in a separate file “finland.zip”

### Classification as an inquiry-oriented activity

We make observations and classifications since we are born. Classification includes for example categorizing 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.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Motion and balance | Vibration and wave motion, sound | Thermal phenomena, light | Optics | Electromagnetism, electricity and magnetism, modern physics |  |

*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, for instance, can be classified into pure materials and compounds.

*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 concepts to their previous knowledge. This presumes that a meaning has to be created for the concept 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 there are between the artefacts/ phenomena?” “How are the artefacts/ entities/ phenomena similar?” “Organize the artefacts/ entities according to their size/ mass/ roughness of the surface/ necessity.” “In which order did things happen?” Teacher’s questions help therefore the students to compare the artefacts/ phenomena under examination and map their similarities and differences. Classification process requires that the 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 on months and temperatures and rain falls.

*Classification method*

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

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

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).



*The phases of concept attainment through classification*

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 student is more actively involved than in the previous method. This approach thus provides that the teacher is patient and guides the students.

*Classifying kitchen supplies on the basis of their material*

Kitchen supplies can be classified at least into four groups. Group one consists of metal artefacts, group two of plastic artefacts, group three of paper artefacts and group four of glass artefacts. The classification can lead to very varied further discussion. For instance, one may discuss recycling at home or how different materials are suited for different uses. Can you think of any other ways of classifying kitchen supplies?

This kind of classification exercise is suitable for situations in which one practices classification. The students can be divided into groups of two, three or four to classify artefacts. The teacher can also collect samples of similar classification data in bags and then give the bags to the students for classification.



*Figure . Classifying kitchen supplies on the basis of their material*

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

The Predict, Observe, Explain (POE) strategy is used in the unit within the science inquiry activity and the students are guided in this activity with a student worksheet. A POE activity includes following phases:

Predict: Students are presented with a worksheet and a particular set-up of equipment, and described what s/he will 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 the case they do not have any conceptional models or representations on the phenomena. Therefore before the prediction phase, it should be discussed with the students and helped them to recognise their own models. For example, classification exercises can help students to recognise their existing models based on their experiences.

Observe: The activity is carried out, and the results are observed and written down.

Explain: The students attempts 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 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.

### Overview of the Jigsaw method used in the unit

The jigsaw classroom is a cooperative learning technique. The syntax is:

|  |  |
| --- | --- |
| 1. Divide students into *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.  3. Divide the lesson into 5-6 segments.  4. Assign each student to learn one segment, making sure students have direct access only to their own segment.  5. Give students time to read over their segment at least twice and become familiar with it. There is no need for them to memorize 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 and to rehearse the presentations they will make to their jigsaw group.  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 realize what they have learned.  **Instructions for the team leader**  Tell the instructions to the team.  Each of the team members works in an inquiry group. Each group has three tasks.  Members of the inquiry group will make a list of notes about every task.  Pupils go back to their home group after finishing the task.  Each team member will tell the results of the inquiry task shortly in his/her own turn and the others write them down into their blocks.  Divide the inquiry tasks.  Make sure, that everyone reads the first paper. | *4-person jigsaw groups*  *Set up jigsaw groups*  *4-person temporary "expert groups"*    *4-person jigsaw groups* |

**4-person temporary ”expert groups” 1**

There are three tasks for the group to accomplish. Agree on if you will work together or divide the tasks.

Remember, that each member of the group has to report all three tasks to his/her home group.

Start from the Science Inquiry Classroom.

Tasks:

-Dropping test

-Ripping test

-What different kinds of intended use there are for paper and cardboard? (Literature or the Internet)

**4-person temporary ”expert groups” 2**

There are three tasks for the group to accomplish. Agree on if you will work together or divide the tasks.

Remember, that each member of the group has to report all three tasks to his/her home group.

Start from the Science Inquiry Classroom.

Tasks:

-Conductivity test

-Bending test

-What different kinds of intended use there are for metal? (Literature or the Internet)

**4-person temporary ”expert groups” 3**

There are three tasks for the group to accomplish. Agree on if you will work together or divide the tasks.

Remember, that each member of the group has to report all three tasks to his/her home group.

Start from the Computer Classroom.

Tasks:

-Heat conductivity test

-Drop test

-What is the raw material for the paper and how is it manufactured? (Literature or the Internet)

**4-person temporary ”expert groups” 4**

There are three tasks for the group to accomplish. Agree on if you will work together or divide the tasks.

Remember, that each member of the group has to report all three tasks to his/her home group.

Start from the Computer Classroom.

Tasks:

-Conductivity test

-Ripping test

-What is the raw material for metal and how is it manufactured? (Literature or the Internet)

**Tasks for Internet activity**

During the Jigsaw working each of 4-person temporary ”expert groups” had tasks for clarifying issues from the Internet. The task was: The expert group should become familiar with the following themes. Each student in the ”expert group” should teach to the team members of the jigsaw group (the students were working rather loosely in the expert groups). In all tasks it was mentioned that the students should use the Internet or literature (an encyclopedia). There were no special hints what resource in the Internet the students should use because they have been working frequently with the computers and the Internet. Some of the students used Google and some Wikipedia.

Tasks for the “expert group”

**4-person temporary ”expert groups” 1**

-What different kinds of intended use there are for paper and cardboard? (Literature or the Internet)

**4-person temporary ”expert groups” 2**

-What different kinds of intended use there are for metal? (Literature or the Internet)

**4-person temporary ”expert groups” 3**

-What is the raw material for the paper and how is it manufactured? (Literature or the Internet)

**4-person temporary ”expert groups” 4**

-What is the raw material for metal and how is it manufactured? (Literature or the Internet)

After the expert groups become familiar with the themes mentioned above, the students in their jigsaw groups taught the mentioned themes to their peers in their jigsaw groups. That was happening during the next lessons.

### ICT tools used in the unit

In the module students search on relevant information over the Internet, read texts and write. Concept maps are drawn and analysed using a CmapTools. The concept-mapping using CmapTools is analysed next in detail.

Novak and Gowin (1984) designed a concept map technique alongside with 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 organise their thinking, and summarising 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). Technology 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 facilitates the building and manipulation of concept maps. More info about use of cmapTools can be found from the CmapTools help (http://cmap.ihmc.us/Support/Help/)

### Hints and tips

During the activities, the students are using web pages and other resources which have been published by firms. Therefore, there are commercial interests in the information resources.

### References to unit

Coffey, J. W., Cañas, A. J., Reichherzer, T., Hill, G., Suri, N., Carff, R., Mitrovich, T., & Eberle, D. (2003). Knowledge Modeling and the Creation of El-Tech: A Performance Support System for Electronic Technicians. *Expert Systems with Applications, 25*(4)

Coffey, J. W., Hoffman, R. R., Cañas, A. J., & Ford, K. M. (2002). *A Concept-Map Based Knowledge Modeling Approach to Expert Knowledge Sharing.* Paper presented at the Proceedings of IKS 2002 - The IASTED International Conference on Information and Knowledge Sharing, Virgin Islands.

Ford, K. M., Coffey, J. W., Cañas, A. J., Andrews, E. J., & Turner, C. W. (1996). Diagnosis and Explanation by a Nuclear Cardiology Expert System. *International Journal of Expert Systems, 9*, 499-506.

Joyce, B. & Weil, M. (1980) Models of Teaching. Englewood Cliffs, N.J.: Prentice-Hall.

Novak, J. D. (1977). *A Theory of Education*. Ithaca, NY: Cornell University Press.

Novak, J. D. (1998). Learning, Creating, and Using Knowledge: Concept Maps as Facilitative Tools in Schools and Corporations. Mahwah, NJ: Lawrence Erlbaum Associates.

Novak, J. D., & Gowin, D. B. (1984). *Learning How to Learn*. New York: Cambridge University Press.

## Unit 2: Activity-Based Site Visit to an Establishment Producing Modern Materials

**Subject area**: Physics, Chemistry, Career counselling

**Grade level**: Grades 8 - 10 / age 14 - 17

**Anticipated teaching time**: 5 – 10 hours

### Intended Learning Outcomes

The main intent is that students will learn within the industry site visit basics of the material science subject knowledge and methods of science applied in the industrial site. The students will became familiar with careers in industrial site and the visit will increase student motivation to study science.

In detail the students will

1. Understand basics of science concepts, principles, and systems in the field of material science site (appropriate to grade level):

* know names of basic materials and terminology used in describing them;
* understand meaning of 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;
* can explain relevant systems or processes met in the site;

2. Use basic science process skills appropriate to the context of materials science and grade level:

* make observations and measurements;
* develop and use categories to classify observations;
* 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 and describe relationships between them;
* formulate questions and set aims to the tasks;
* plan field study/ interview;
* collect and record data;
* analyse data and draw warranted inferences.

4. Increase motivation and interests:

* maintain a sense of curiosity about natural phenomena;
* maintain interest toward 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 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 properties of them;
* understand how technological advances have influenced the progress of science and how science has influenced developments in technology;
* recognise the personal relevance of science in daily life;
* respect the contributions of science and technology to the quality of human life;
* recognise the interdependence of science, technology, and society;
* recognise the possibility for a career in science and technology.

6. Communicate effectively using science language and reasoning:

* use the language and concepts of science as a means of thinking and communicating;
* prepare written and oral reports describing the findings of investigations and the reasoning which led to the conclusions;
* report results honestly;

7. Understand the nature of science and technology:

* understand that science is an inquiry process used by humans to construct knowledge based upon observable evidence;
* understand that technology is a creative discovery process used by humans to design usable artefacts;
* distinguish between science and technology;
* recognise the vital need for creative thinking and imagination in designing and conducting scientific inquiry and technological processes.

### Recommended settings and pedagogical approaches

During the unit an industrial site visit will be organised. Students will engage in planning the visit and activities before, during and after the visit. 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 unit to the students.

**Introduction**

For the time of preparing the visit, the site visit itself and working after the visit the students adopt a role of a reporter. Constructivity and contextuality are characteristic features to this kind of way of working. Constructivity means that the students systematically and actively connect new information to the knowledge basis they constructed earlier. Contextuality means that students learn science and writing activities in a real-life kind of situation. Compiling the reportage in a group supports co-operative learning and social relatedness. Students share the duties so that everyone in the group is responsible of his or her own sector. While the working proceeds, students let other members of their group assess and comment their accomplishments and then elaborate them further.

**Preparation of the visit**

Before the site visit students find out what reporters do and how to write a reportage. When working as reporter students first get acquainted with the subject, then plan the perspective of their own reportage and then find a specific focus for their topic, if needed. After getting familiar with the home page of the company to be visited the students choose the perspective of their own reportage. It can be, for example, ‘materials used in the production’, ‘raw materials and their origins’, ‘utilizing nanotechnology in the products of the site’, ‘different occupations and the education needed for these occupations’ or ‘where the products of the site are used’. Students plan the aim of their reportage 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 to.

The students will prepare a preliminary concept map reflecting their previous knowledge about material science issues, the processes in the industry site and professions in the site.

**Site visit**

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

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

**Working after the visit**

After the site visit students write a reportage that is based on their notes and interviews and recordings of the interviews. The technique of writing this reportage is similar to process writing (chapter 6.4), because a writer lets his or her group members read his or her drafts, and elaborates them further after the feedback given to him/her.

After the presentations of articles the student’s learning and the industry site visit are evaluated by a questionnaire and concept maps.

### Material resources including ICT tools

In the module students search on relevant information over the Internet, read texts and write (see chapter 6.4).

### Hints and Tips

During the activities, the students are using web pages and other resources which have been published by firms. Therefore, there are commercial interests in the information resources.

# C. Description of Extension Activities

The student’s booklet of the Materials around us –module contains several exercises. In the beginning of the module the exercises offer a way of teaching classification and inquiry as methods of work to the students. In later chapters the exercises are situated in the end of the chapter and all require written answers. All of the exercises may be used in a variety of ways depending on the approach that the teacher sees as appropriate for the group.

Especially the exercises in the first chapter may be very teacher lead and this gives the teacher a possibility to check the level of competence of the students. If the teacher believes that the students are capable of working on their own they may do so or work in small groups possibly following one of the methods proposed in the Teacher guide.

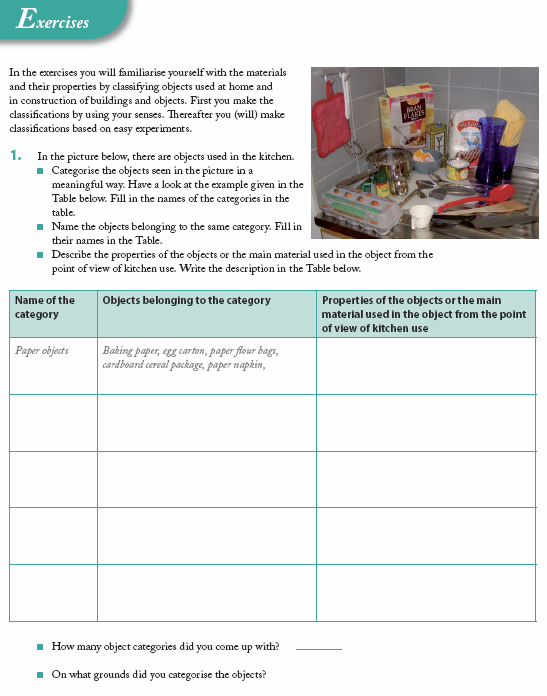
In the following chapters all exercises are situated in the end of the chapter and can either be used as homework as repetition outside classroom or they may be solved as group work in the classroom. It is also possible to use the exercises as a guide for pointing out the important parts of the text. This may help the students to develop efficient reading strategies.

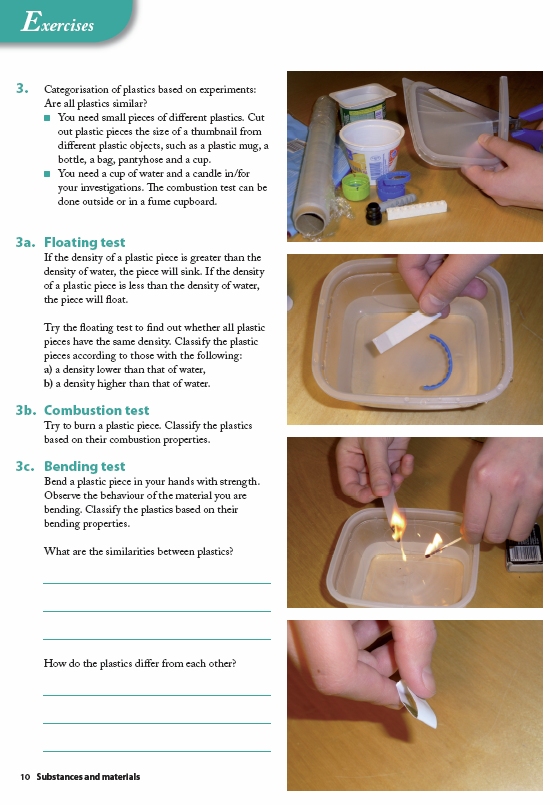
In the fifth chapter of the student booklet there are several POE (predict, observe, explain) -type inquiry activities which can be conducted in several ways. It is important for the teacher to guide the students to use the method correctly since it may be a new way of working for the students in similar ways as the classification tasks in the first chapter.

The module consists of several activities that may easily be extended to cover other important materials in the surroundings of the students or to further explore the connection of the material science to the society. Also it is possible to develop the reading and writing skills of the students. Useful ways of using reading and writing activities in teaching are described in the Teacher guide in chapter 6.4.

For example the students could write a blog or journal and include in this blog information that they have found in other media. Reporting the course of the module and tasks in the classroom and the student’s own learning results in a journal may also be useful. The students are meant to act as journalists and write an article of their site visit but also this method may be practised before the site visit in school. Articles may be written of other companies, branches of industry or materials. It may be useful to concentrate on the materials, materials science and inquiry activities in the beginning of the module and after the site visit to concentrate more on the society aspect.

Examples of learning to learn by reading and writing are also given in chapter 6.4. It is possible to practise these skills in the beginning of the module when the students are familiarising with the different materials. Processing the text in the student’s booklet and synthesising it with information found in other media may be useful especially if different stages of process writing are taken into consideration as described in chapter 6.4.

****

****

# D. Evaluation tasks for individual activities or individual Units or whole module

## Pre-test, post-tests

### UNITS 1 & 2

The student learning in the module may be assessed by conventional examinations and/or using some of the assessment tools that have been developed for the research project. One assessment tool for evaluating student knowledge of the material, its uses and structure is included. There are also changes in the students’ affective domain that may be assessed by likert-type questionnaires. The implementation of the module may also be evaluated which will result in information that can be used when planning the next site visit.

One way of assessing student work during the module is to use the student worksheet from the Predict, observe, explain –tasks in student booklet’s chapter five. Below are included the “correct” answers for the POE-tasks. When assessing the student answers in these worksheets it should be kept in mind that the predictions are not supposed to be correct. Wrong predictions may even help to learn the phenomenon. Also the student observations may be more useful in pointing out the defects of the course of the lesson than assessing student knowledge.

What is possible to evaluate in the POE-worksheets is the use of the models of the materials in the explanations. In several cases the student may refer to his/her prediction or observations in their explanations and thus those should also be read when evaluating the answer. When students use their models in written answers they will show any misunderstandings. Using models of materials and their structure is new to the students so they will hesitate to use them in their explanations. To make the assessment fair, the teacher needs to emphasise the use of the models for the students.

Also included below is the self-evaluation sheet that may be distributed to the students after the industry site visit in which the students may report their own assessment of their learning and the positive and negative sides they have experienced on the site visit. This will result in information that the teacher may consider when planning another site visit.

If concept maps are used during the module, the students will form appropriate skills already during the module so that they may produce concept maps that can be used in evaluation purposes in the end of the module. This may be a useful way of assessing both the student learning and evaluating the successfulness of the module implementation. CmapTools may be used for the production of the concept maps. It also facilitates 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.

|  |  |
| --- | --- |
| **Dropping test** |  |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  |  | |  | |
|  | 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. | |
| **Predict**  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. | *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.* | *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.* | | *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.* | |
| **Observe**  What happens in the test? | *The paper broke and a linear hole was formed.* | *The plastic foil was strained under the ball but recovered and the ball was thrown back. The plastic foil didn’t break easily.* | | *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.* | |
| **Explain**  How can the observed phenomena be explained with models? How are the particles of the material organised in the material? | *The interactions between fibres are weak. That is why the paper more easily rips in the direction of the fibres.* | *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.* | | *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.* | |
| **Conductivity test** | | |  | |

|  |  |  |  |
| --- | --- | --- | --- |
|  |  |  |  |
|  | 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. |
| **Predict**  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. | *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.* | *Plastic doesn’t have any free electrons to conduct electricity. All the electrons are located in the polymer molecules. Plastic doesn’t conduct electricity.* | *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.* |
| **Observe**  What happens in the test? | *When a piece of paper was connected to the circuit, the lamp was not lit.* | *When a plastic object was connected to the circuit, the lamp was not lit.* | *The lamp went on when a piece of metal was connected to the circuit.* |
| **Explain**  How can the observed phenomena be explained with models? How are the particles of the material organised in the material? | *Paper does not conduct electricity since there are no free electrons to do so.* | *Plastic material doesn’t conduct electricity since there are no free electrons in plastic to do so.* | *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.* |

|  |
| --- |
| **Ripping test** |

|  |  |  |  |
| --- | --- | --- | --- |
|  |  |  |  |
|  | 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. |
| **Predict**  What will happen in the test? Base your prediction on the micro models of the materials. | *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 interactions between the fibres.* | *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.* | *The metal lattice is similar everywhere so the direction of tearing doesn’t make a change.* |
| **Observe**  What happens in the test? | *Paper rips more easily and straight in the other directions. When ripped in the other direction, the rip tends to turn.* | *Plastic first stretches and then rips unevenly.* | *Aluminium foil rips as easily and unevenly from all directions.* |
| **Explain**  How can the observed phenomena be explained with models? How are the particles of the material organised in the material? | *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.* | *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.* | *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.* |

|  |
| --- |
| **Heat conductivity test** |

|  |  |  |  |
| --- | --- | --- | --- |
|  |  |  |  |
|  | 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. |
| **Predict**  What will happen in the test? Base your prediction on the micro models of the materials. | *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.* | *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.* | *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.* |
| **Observe**  What happens in the test? | *The butter on the cardboard melts slower than on metal.* | *The butter on the plastic spoon melts slower than on metal.* | *The butter on metal melts first.* |
| **Explain**  How can the observed phenomena be explained with models? How are the particles of the material organised in the material? | *The cardboard conducted heat very slowly because it hasn’t got free electrons and it’s very porous which also slows down the conductivity.* | *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.* | *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.* |

|  |
| --- |
| **Bending test** |

|  |  |  |  |
| --- | --- | --- | --- |
|  |  |  |  |
|  | 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. |
| **Predict**  What will happen in the test?  Base your prediction on the micro models of the materials. | *When paper is rolled up it will bend really well but when the weak interactions between the fibers fail, paper will stay curvy.* | *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.* | *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.* |
| **Observe**  What happens in the test? | *Paper is bended easily but doesn’t return from the bended position very well.* | *Plastic bends well and returns back to original shape.* | *Metal can be bended a lot but doesn’t return to its original shape.* |
| **Explain**  How can the observed phenomena be explained with models? How are the particles of the material organised in the material? | *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.* | *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.* | *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.* |

|  |
| --- |
|  |

|  |  |  |  |
| --- | --- | --- | --- |
|  |  |  |  |
|  | 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. |
| **Predict**  What will happen in the test? Base your prediction on the micro models of the materials. |  |  |  |
| **Observe**  What happens in the test? |  |  |  |
| **Explain**  How can the observed phenomena be explained with models? How are the particles of the material organised in the material? |  |  |  |

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

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:

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.

**EVALUATION OF SCIENCE INQUIRY ACTIVITIES**

**DATE: \_\_\_\_\_\_\_\_\_\_ COUNTRY: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ NAME: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

For each of the following statements dealing with scientific inquiry activities, please indicate how true it is for you, using the following scale: **not at all true (1)** … **very true (7)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **When I engage in science inquiry activity …** | | not at all somewhat very  true true true | |
| 1. | I enjoy the activity very much. | 1 2 3 4 5 6 7 | |
| 2. | I think I am pretty good at the activity. | 1 2 3 4 5 6 7 | |
| 3. | I put a lot of effort into the activity. | 1 2 3 4 5 6 7 | |
| 4. | I did not feel nervous at all while doing the activity | 1 2 3 4 5 6 7 | |
| 5. | I believe I had some choice about doing the activity. | 1 2 3 4 5 6 7 | |
| 6. | I believe the activity has some value for me. | 1 2 3 4 5 6 7 | |
| 7. | I feel really distant from my peers while doing the activity. | 1 2 3 4 5 6 7 | |
| 8. | The activity is fun to do. | 1 2 3 4 5 6 7 | |
| 9. | I think I do the activity pretty well, compared to other students. | 1 2 3 4 5 6 7 | |
| 10. | I didn’t try very hard to do well at the activity. | 1 2 3 4 5 6 7 | |
| 11. | I felt very tense while doing the activity. | 1 2 3 4 5 6 7 | |
| 12. | I felt like it was not my own choice to do the activity. | 1 2 3 4 5 6 7 | |
| 13. | I think that doing the activity is useful for my science studies. | 1 2 3 4 5 6 7 | |
| 14. | I really doubt that my peers and I would ever be successful team through the activity. | 1 2 3 4 5 6 7 | |
| 15. | The activity is boring. | 1 2 3 4 5 6 7 | |
| 16. | After working at the activity for a while I feel pretty competent. | 1 2 3 4 5 6 7 | |
| 17. | I tried very hard on the activity. | 1 2 3 4 5 6 7 | |
| 18. | It was important to me to do well at the activity. | 1 2 3 4 5 6 7 | |
| 19. | I was very relaxed in doing the activity. | 1 2 3 4 5 6 7 | |
| 20. | I didn’t really have a choice about doing the activity. | 1 2 3 4 5 6 7 | |
| 21. | I think the activity is important to do because it can help me in learning | 1 2 3 4 5 6 7 | |
| 22. | I feel I could really trust my peers participating in the activity. | 1 2 3 4 5 6 7 | |
| 23. | The activity did not hold my attention at all. | 1 2 3 4 5 6 7 | |
| 24. | I am satisfied with my performance at the activity. | 1 2 3 4 5 6 7 | |
| 25. | I didn’t put much energy into the activity. | 1 2 3 4 5 6 7 | |
| 26. | I was anxious while working on the activity. | 1 2 3 4 5 6 7 | |
| 27. | I felt like I had to do the activity. | 1 2 3 4 5 6 7 | |
| 28. | I would be willing to do similar activities more because they have value for me. | 1 2 3 4 5 6 7 | |
| 29. | I’d like to interact with my peers participating in the activity more often. | 1 2 3 4 5 6 7 | |
| 30. | I would describe the activity as very interesting. | 1 2 3 4 5 6 7 | |
| 31. | I am pretty skilled at the activity. | 1 2 3 4 5 6 7 | |
| 32. | I felt pressured while doing the activity. | 1 2 3 4 5 6 7 | |
| 33. | I do the activity because I have no other choice. | 1 2 3 4 5 6 7 | |
| 34. | I think doing the activity could help me to learn science. | 1 2 3 4 5 6 7 | |
| 35. | I feel close to my peers during the activity. | 1 2 3 4 5 6 7 | |
| 36. | I think the activity is quite enjoyable. | 1 2 3 4 5 6 7 | |
| 37. | I couldn’t do the activity very well. | 1 2 3 4 5 6 7 | |
| 38. | I do the activity because I want to do it. | 1 2 3 4 5 6 7 | |
| 39. | I believe that doing the activity could be beneficial for me. | 1 2 3 4 5 6 7 | |
| 40. | I don’t feel like I could really trust my peers who are participating in the activity. | 1 2 3 4 5 6 7 | |
| 41. | When I am doing the activity, I think about how much I am enjoying it. | 1 2 3 4 5 6 7 | |
| 42. | I do the activity because I have to do. | 1 2 3 4 5 6 7 | |
| 43. | I think the activity is an important activity. | 1 2 3 4 5 6 7 | |

Appendix 2.Questionnaire 2

**ACADEMIC MOTIVATION for learning science**

**DATE: \_\_\_\_\_\_\_\_\_\_\_ COUNTRY: \_\_\_\_\_\_\_\_\_\_\_\_\_\_ NAME: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

***WHY DO I LEARN SCIENCE?***

Using the scale below, indicate to what extent each of the following items presently corresponds to one of the reasons why you learn science.

Does not correspond Corresponds Corresponds Corresponds Corresponds

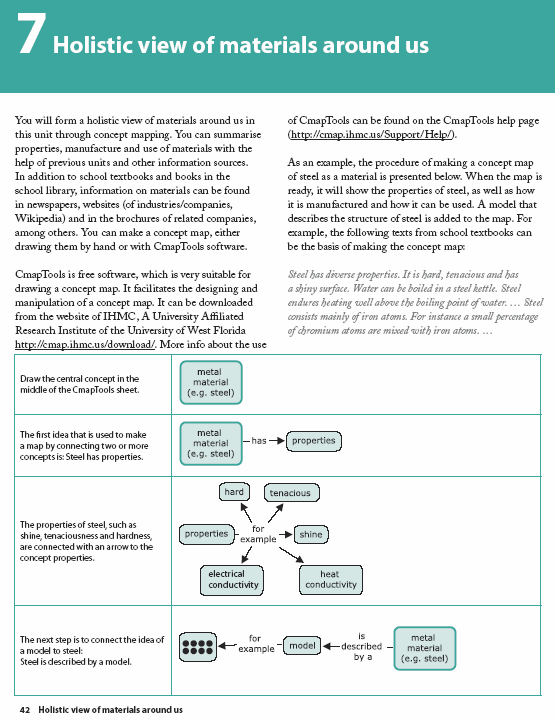
at all a little moderately a lot exactly

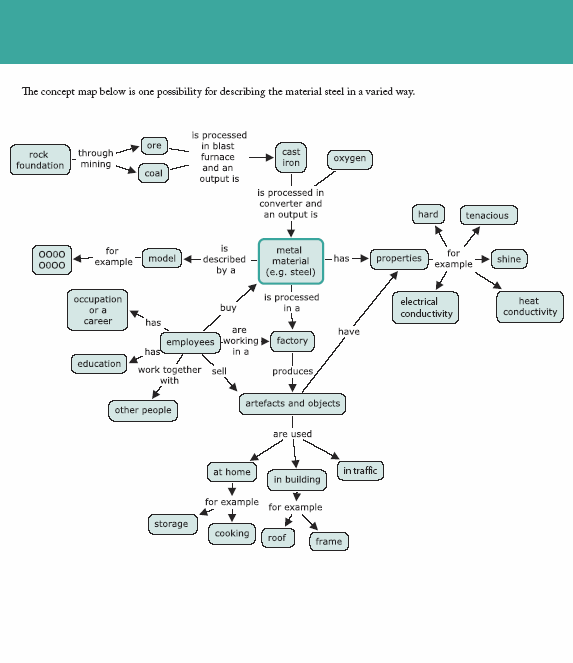
1 2 3 4 5 6 7

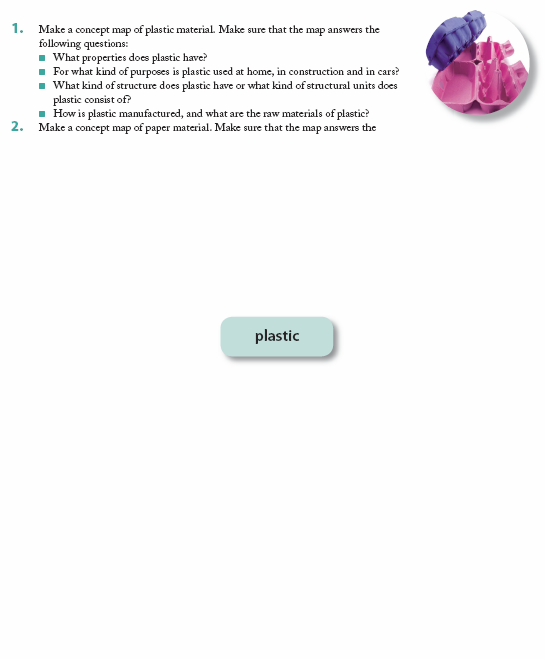
|  |  |  |  |
| --- | --- | --- | --- |
|  | **Why do I learn science?** | Does not  correspond Corresponds Corresponds  at all moderately exactly | |
| 1. | Because I have the impression that it is expected of me. | | 1 2 3 4 5 6 7 | |
| 2. | To show myself that I am a good student. | | 1 2 3 4 5 6 7 | |
| 3. | Because I choose to be the kind of person who knows many things as an adult. | | 1 2 3 4 5 6 7 | |
| 4. | Because it’s important to me to learn science. | | 1 2 3 4 5 6 7 | |
| 5. | Because I enjoy the feeling of acquiring knowledge about science. | | 1 2 3 4 5 6 7 | |
| 6. | For the enjoyment I experience when I grasp a difficult subject in science. | | 1 2 3 4 5 6 7 | |
| 7. | Because it will help me make a better choice regarding my career orientation. | | 1 2 3 4 5 6 7 | |
| 8. | For the "high" feeling that I experience when I am taken by discussions with interesting science teachers. | | 1 2 3 4 5 6 7 | |
| 9. | Because studying science allows me to continue to learn about many things that interest me. | | 1 2 3 4 5 6 7 | |
| 10. | Because I think it is good for my personal development. | | 1 2 3 4 5 6 7 | |
| 11. | For the pleasure that I experience in knowing more about science. | | 1 2 3 4 5 6 7 | |
| 12. | Because I would feel ashamed if I couldn’t discuss with my friends about things concerning science. | | 1 2 3 4 5 6 7 | |
| 13. | I don’t know why I study science, and frankly, I don’t give a damn. | | 1 2 3 4 5 6 7 | |
| 14. | In order to get a more prestigious job later on. | | 1 2 3 4 5 6 7 | |
| 15. | For the "high" feeling that I experience while reading about various interesting science subjects. | | 1 2 3 4 5 6 7 | |
| 16. | Because science learning allows me to experience a personal satisfaction in my quest for excellence in my studies. | | 1 2 3 4 5 6 7 | |
| 17. | Because I really like science learning. | | 1 2 3 4 5 6 7 | |
| 18. | Because I would feel guilty if I didn’t study science. | | 1 2 3 4 5 6 7 | |
| 19. | Because I’ll get in trouble if I don’t do so. | | 1 2 3 4 5 6 7 | |
| 20. | For the pleasure I experience when surpassing myself in science studies. | | 1 2 3 4 5 6 7 | |
| 21. | Honestly, I don’t know, I truly have the impression of wasting my time in studying science. | | 1 2 3 4 5 6 7 | |
| 22. | I once had good reasons for learning science; however, now I wonder whether I should continue. | | 1 2 3 4 5 6 7 | |
| 23. | Because I choose to be the kind of person who knows matters concerning science. | | 1 2 3 4 5 6 7 | |
| 24. | For the satisfaction I feel when I am in the process of accomplishing difficult exercises in science. | | 1 2 3 4 5 6 7 | |
| 25. | Because I want the teacher to think I’m a good student. | | 1 2 3 4 5 6 7 | |
| 26. | For the satisfied feeling I get in finding out new things. | | 1 2 3 4 5 6 7 | |
| 27. | Because for me, science learning is fun. | | 1 2 3 4 5 6 7 | |
| 28. | I don’t know why I am studying science. | | 1 2 3 4 5 6 7 | |
| 29. | In order to have a better salary later on. | | 1 2 3 4 5 6 7 | |

## 

## Concept maps







# E. Brief Description of Module Design, Development and Validation process

The modules have been designed by the Local Working Group (LWG). The LWG have had seven meetings where the literature review and preliminary modules has been discussed. A memorandum has been written and all decisions have been written to the memorandums. Between the meetings individual researchers were writing, rewriting and modifying the prototype modules. In the middle of working (before Barcelona meeting) a status report was written.



*The design procedure of the modules*

As a methodological framework for module design, we have used a design-based research approach (DBR) that has been suggested as a solution for the discontinuation between educational research and praxis (Juuti & Lavonen, 2006). It is a general framework for design, development, implementation and evaluation of learning activities and it uses a pragmatic frame. DBR emphasizes three aspects: (a) a design process is essentially iterative starting from the recognition of the need to change praxis, (b) it generates a widely usable artefact, like learning activities or a learning environment, (c) and it provides educational knowledge for more intelligible praxis. In the knowledge acquisition process, the pragmatic viewpoint emphasizes the role of a teacher’s reflected actions as well as the researches’ involvement in the authentic teaching and learning settings (Design-Based Research Collective, 2003; Bell, Hoadley, & Linn, 2004).

DBR comprises of the combination of theory development, the prescriptions of successful design processes, and the prescriptions of successful design solutions. The design procedure contains four main phases: 1) needs assessment; 2) theoretical problem analysis and definition of the objectives for a design solution, artifact; 3) design and production of the artifact; and 4) evaluation of the artifact. During the design and production phase, there are typically several cycles: designing of a prototype, evaluation of the prototype in real classroom settings, revising the objectives based on the evaluation, and re-designing. This phase together with needs assessment can also be called the empirical problem analysis (Edelson, 2002).

During the theoretical problem analysis relevant existing knowledge or answers to identified research problems are searched from the available research literature. In the beginning, designers typically have a tentative strategy by which to manage the problem. One approach to generate these tentative strategies is to use creative problem solving methods. The design team produces the first prototype based on theoretical problem analysis and needs assessment. Empirical problem analysis is concerned with designing and evaluating the design solution, artefact. Evaluation may employ multiple methods as Bell, Hoadley, and Linn (2004) have proposed. The main tool is coordinated communication between teachers (users of the artefact) and researchers (designers). Throughout the communication, researchers help teachers to articulate their experiences gained whilst teaching. Thus, it is not just an individual experience any more, but knowledge about teaching and learning which has been constructed. The theoretical and empirical problem analysis ensure that the designed activities are easy to integrate into school practice

Research on out-of-school learning has a history of over 100 years (Hein & Alexander, 1998), while studies that focus specifically on learning and cognition have gained considerable momentum in the past 20 years (see the reviews of Dierking & Falk, 1994 and Ramey-Gassert, Walberg, & Walberg, 1994; Hooper-Greenhill & Moussouri, 2003). Wide variety of approaches and methodologies has been employed in these studies. The research reported here is a case study because this approach can penetrate situations in ways that are not always susceptible to numerical analysis (Yin, 1994). One of the strengths of a case study is that it can observe effects in real contexts and recognize that context is a powerful factor of both causes. Empirical data in this case study was collected by video recording, student interviews, interviewing the teacher, and a questionnaire to evaluate the outcomes of the visit. The data allow triangulation and suggest that versatility of the designed site visit model helps in creating active school-society interrelations, motivating students in science studies, and provides models for future career choices. However, we will use in this preliminary research mainly the questionnaire data.

## Theoretical problem analysis

Our theoretical problem analysis on learning is based on recent studies on how people learn science by Bransford, Brown and Cocking (2000) and Bransford and Donovan (2005). According to these books, learning represents each individual learner’s own personal knowledge construction process which presupposes each learner’s active, goal-oriented and feedback-seeking role. Meaningful learning engages students in tackling the topic to be learnt in such a way that they create meaningful and understandable knowledge structures on the basis of a given topic. The constituents of meaningful learning are the following: activity, intention, contextualization, construction, collaboration, interaction, reflection, and transfer. These serve as development criteria for our module.

*Activity and intention* mean that students take responsibility over their own learning. Thus they set their learning goals and proceed according to the plan to reach the set goal. This process may be facilitated, for example, by guiding students to plan by themselves or in small collaborative groups. Activity may be enhanced also by self-evaluating. *Reflection* means that students examine their own learning and develop metacognitive skills to guide and regulate their learning. Metacognitive skills are necessary for planning and evaluating one’s own work. For example, self-evaluating or evaluating in a small group, taking multiple-choice tests, doing exercises and consulting answer keys support developing reflective skills. *Collaboration and interaction* mean that students actively take part in group activities and support each other by discussing and sharing knowledge. For example, new contacts and discussions during the site visit give variety to interaction. *Construction and contextualization* mean that students combine their earlier knowledge with the new topics to be learnt and thereby tailor information structures that they can comprehend. Thus learning takes place in real life situations or in situations simulating real-life instances. This in turn presupposes that the learning setting allows for authentic and real-life learning experiences. From the point of view of interestingness, the context in which science ideas are learned, rather than the ideas themselves, have important influence on learning. For instance, when writing it is crucial that students write to prospective readers other than the teacher.

Previous characteristics of learning activity may be realised through site visits and the use of ICT. For example, by employing the Internet in the planning phase of a visit, students have access to meaningful information about the site to be visited. 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.

According to Ryan and Deci (2002), a person’s way of thinking has an important role in the process of motivation. Motivated behaviour may be (i) *self-determined* or (ii) *controlled* and they involve different reasons for behaving. Self-determined or autonomous behaviour is behaviour which arises freely from one's self. Controlled behaviour, in contrast, means that the behaviour is "controlled by some interpersonal or intrapsychic force, like a curriculum”. The motivation styles in SDT are *extrinsic* and *intrinsic motivation*. Intrinsic motivation has positive effects on the quality of learning. Intrinsically motivated behaviours are based on the need to feel competent and self-determined (Deci & Ryan, 2000). Extrinsically motivated behaviour is instrumental in nature. Such action is performed for the sake of some expected outcome or extrinsic reward or in order to comply with a demand.

Although students primarily produce their motivation, it can be enhanced and learned. In practice, a science teacher can offer optimal challenges and a rich source of stimulation and arouse feelings of autonomy, for example, by choosing *activities* such as open investigation (Wellington, 1998) or a site visit which has been planned together with a teacher and students. In these situations, positive feedback enhances intrinsic motivation when students feel responsible for a competent performance.

Interest is a content-specific motivational variable (Krapp, 2007). Interest is approached from two major points of view. One is interest as a characteristic of a person (*personal interest*) and the other is interest as a psychological state aroused by specific characteristics of the learning environment (*situational interest*). Personal interest is topic specific, persists over time, develops slowly and tends to have long-lasting effects on a person’s knowledge and values (Hidi, 1990). Pre-existing knowledge, personal experiences and emotions are the basis of personal interest (Schiefle, 1991). *Situational interest* is spontaneous, fleeting, and shared among individuals. It is an emotional state that is evoked by something in the immediate environment and it may have only a short-term effect on an individual’s knowledge and values. Situational interest is aroused as a function of the interestingness of the topic or an event and is also changeable and partially under the control of teachers (Schraw & Lehman, 2001).

According to Hoffman (2002), an appropriate context where certain physics or chemistry contents or topics are met or the type of selected learning activity (teaching method) might have an influence on the quality of emotional experience, which is important for the development of situational interest. Juuti, Lavonen, Uitto, Byman, and Meisalo (2004) surveyed Finnish 9th grade students’ interests in physics in certain contexts. The most interesting things (especially for girls) were connected with human being. Therefore, during the site visit, it is important to approach issues through the activities of human beings. Students’ out-of-school experiences are different. Boys’ experiences are more relevant to physics and technical topics whereas those of girls’ are more closely related to everyday life and health (Uitto, Juuti, Lavonen & Meisalo, 2006). Therefore science related experiences and role models (teacher, visitors, contacts during site visits, ...) are important especially for girls.

Lewalter and Krapp (2004) have introduced a concept, *vocation-related interest,* which refers to a specific topic or area, a certain kind of activity or characteristic of occupation. According to the literature review of Unwin, Fuller, Turbin, and Young (2004), young people’s occupational choices, in general, reflect the nature of the education and training system and the youth labour market. Several other reasons, such as students’ learner identity have an effect on occupational choice (Biggart, 2002). Lavonen, Juuti, Byman, Uitto, and Meisalo (2006) examined lower secondary school students’ interests in the characteristics of occupations or careers. Students, in general, appreciated an occupation allowing time for their interests, creativity activities, and social interaction.

The *Self-Determination Theory* (SDT) and *Theory of Interest* are relative theories. Especially from the point of view of site visits, similar conclusions can be done based on both theories. For example, it is important to support student autonomy for increasing his or her interest or motivation to learn. Moreover, occupational orientations can be influenced during the site visit through role models.

## Design Solution: a prototype module of the site visit

While we have chosen to place emphasis on practical research-based designing of the materials science module we have first striven to develop alternative approaches and educational innovations based on the theoretical problem analysis. Altogether we generated seven possible design solutions. However, here we will discuss only the site visit. Although we present a model for a site visit, ithas to be applied in a flexible way. The model is based on the previous study of Kuitunen and Meisalo, (1988):

Advance planning by teachers:

preliminary planning on general level by a group of physics and chemistry teachers and a career counselor.

Teacher preparatory site visit:

co-planning with the contact person at the plant.

The preparation of students:

forming of student groups for project work,

the presentation of preliminary goals for the visit,

planning of the tasks and a way of reporting (preliminary questions to the plant),

go-planning of the visit,

students learn about the industrial branch and the plant using Web resources etc.,

preparation and sending of the questions, interesting for students to the site contacts.

The site visit:

introduction (plant, what they are doing, what kind of people are working there),

“sightseeing” around the plant,

different topics as agreed with students.

Student group reports

students prepare the reports,

students present their reports,

discussing what students have learnt and what could be improved.

Evaluation and feedback with teachers and site representatives:

the evaluation of reports and visit.

Collecting ideas for planning future site visits.

## Empirical problem analysis

Although the researchers of the Material Science Project were well aware of the long tradition of site visits in Finland, it was found advisable to organize a preliminary study before involving with the major effort with international dimensions.

The visit was organised 3rd May, 2007 to the material science industry plant based on the previous description of the prototype module of the site visit. The visit was organised in a lower secondary school together with a science teacher and a career counselor in a suburban school in metropolitan Helsinki. In the study group there were 21 students. Transportation by a charter bus was financed by the Association of Technology Industries, Finland. The excursion was recorded on video by one of the authors and feedback was obtained using a very basic form of a questionnaire.

The students gave feedback on the basis of five Likert type questions with alternatives 1 Very little to 5 Very much and an open-form question “*What interested you most during the visit*”? The open responses were classified based on the content to six categories: The most interesting was: 1) science learned during the visit, 2) manufacturing process, 3) the products of the industry, 4) occupations, 5) environmental aspects, and 6) coffee break. In addition there were some general comments: “We learned so much.” and “Nice to learn something new.” The responses to the questionnaire are presented in Table 1 and Table 2.

Table 1. The students’ evaluation of the site visit.

|  |  |  |
| --- | --- | --- |
|  | Mean | S.D. |
| I learned physics and/or chemistry during the visit   (Very little … Very much) | 2.84 | 0.96 |
| I learned about working life and professions during the visit  (Very little … Very much) | 3.32 | 0.89 |
| I learned during the visit how physics and chemistry are applied in practice  (Very little … Very much) | 3.47 | 1.17 |
| I’d like to have industrial visits in school   (Very little … Very much) | 4.16 | 1.12 |
| The industrial visit was in my mind   (Very uninteresting … Very interesting) | 2.74 | 1.1 |

Table 2. The students’ response to the open question “What interested you most during the visit?”

|  |
| --- |
| Most interesting was science learned during the visit  To see how silicon crystals are grown.  To see where physics and chemistry are used in practice. It is difficult to realize it in school. |
| Most interesting was manufacturing process during the visit  The sightseeing in the premises.  To see how silicon wafers are made.  The visit to the production premises, and to see the machine tools.  It was most interesting to see the appliances in action.  The chemical storage hall was interesting. |
| Most interesting was the products of the industry  Where silicon wafers produced by Okmetic are found in electronic appliances in everyday use.  To learn where silicon wafers are used. |
| Most interesting was the occupations  To meet professionals.  The experts did know indeed, what they were presenting. |
| Most interesting was the environmental aspects  To learn how unthinking and egocentric we are. |
| Coffee break  Coffee pause.  Food and coffee.  It was a divine, extraordinary experience to have such a wonderful coffee break! |

Based on the questionnaire data we interpret that the students are willing to have more similar visits. The students felt that they learned most about how physics and chemistry are applied in practice. Second most they learned about working life and professions during the visit. The students learned less about pure physics and/or chemistry during the visit. The qualitative data are rather similar with the quantitative data. It is obvious that there are several comments indicating interest in site visit activities, but also some reflecting the attitude that nothing science-related the school tries to organise can be interesting. Therefore, the learning outcomes belong mainly to the first, personal context, and second, sociocultural context, categories in the model of Falk and Dierking (2000). The discussion about further development of the site visit, third category of the Falk and Dierking model, is presented in the discussion section.

The preliminary questionnaire seems to give valuable feedback, but it will be developed further and probably also essentially augmented to include e.g., items on comparison of site visit experiences with other school and out-of-school experiences and their interests or attitudes. Further feedback will be obtained by analysing the video files recorded during the visit. The student and teacher reports prepared after the visit are also important sources of additional information. We interpret that it shows both learning of some crucial aspects of modern industrial production and interest in related study and career choices.

## Conclusions based on the Preliminary Study and Implications

Based on the experiences and student evaluations of the site visit, focusing of the site visit model is needed. The students feel, they do not learn much physics and chemistry during the visit. Therefore during the teacher preparatory site visit, the teacher should discuss in more detail about the preliminary goals of the visit concerned with the science content. Moreover, the teacher should describe more carefully student’s existing skills and abilities to the contact person. During the preparation of students, more time should be used to the planning of the tasks and the way of reporting (structure of the report, ICT use in reporting, the evaluation of the visit and the report). Students should also prepare their project plans, goals, tasks, reporting planning, more carefully.

The research question in this preliminary phase was not so strictly formulated. Therefore, we have to evaluate the question based on our experiences and the original goals stated in the Project Plan of the Material Science Project. The outline of the set of research questions in the main research may include:

What indications of motivation and interest can be identified during and after site visits?

How the role of ICT is seen during the visits and what ICT skills are practiced by the pupils?

How much relevant information pupils can find in the Internet and other sources prior to the visit and what they learn about modern materials and their use as well as about relevant study possibilities and careers?

In the project meetings of the Local Working Group (LWG) of our Project, it was realised that while the main research question is related to interest change and motivation, a short-time experimental involvement may not have a measurable effect size. Therefore, it was decided to try and plan a sequence of materials science related experiences for an experimental group of lower secondary school pupils. Obviously also the questionnaire instrument for evaluating interest and motivation should be developed further.

In the LWG meeting it was decided that in the second cycle of the design based research the first unit would be developed along the guidelines tested in the above case study. The second unit would be modified from the ideas of “an exhibition on nanotechnology and related modern materials emphasising their applications and needed literacy”. The concretization of these ideas would be in the context of visiting a university laboratory involved in basic materials research. The third unit would be developed on the basis of the idea of “using CMap Tools to analyse plastics and composite materials as interesting examples of new and developing materials around us”. The focus of this development would be on classroom level experimentation. The other ideas presented by the LWG for possible units were evaluated as interesting, but not feasible to be implemented with the resources presently available to our project.

Finally, it was also seen that the next site visit should be planned for spring 2008 and it should be in coincidence with the visit of our Macedonian partners to Finland. It is not seen necessary to produce learning materials for participating pupils, but a short guide leaflet for teachers advising what information pupils will be expected to search in the Internet prior to the visit. Furthermore, general guidelines for pupil teams writing reports on their experiences and what they have learned will be made available to teachers. Furthermore, it was seen advisable to give a list of relevant websites (cf. the list at the end of this paper) to them.

### References

Bell, P., Hoadley, C.M., & Linn, M.C. (2004). Design-based research. In M.C. Linn, E.A. Davis, & P. Bell (Eds.), *Internet environments for science education* (pp. 73-88). Mahwah, New Jersey, Lawrence Erlbaum Associates.

Biggart, A. (2002). Attainment, Gender and Minimum-aged School Leavers: Early Routes in the Labour Market. *Journal of Education and Work, 15*(2), 145-162.

Bransford, J.D. & Donovan, S.M. (2005). *How Students Learn Science in the Classroom*. Washington, D.C.: National Academies Press.

Bransford, J.D., Brown, A.L., & Cocking, R.C. (Eds.) (2000). *How People learn: Brain, Mind, Experience, and School*. Washington, D.C.: National Academy Press

Deci, E.L. & Ryan, R.M. (2000). The “what” and “why” of goal pursuits: Human needs and self-determination of behavior. *Psychological Inquiry*, *11*, 227-268.

Design-Based Research Collective. (2003). Design-based research: An emerging paradigm for educational inquiry. *Educational Researcher, 32*, 5-8.

Dierking, L. & Falk, J. (1994). Family behavior and learning in informal science settings: A review of the research. *Science Education, 78*(1), 57-72.

Edelson, D.C. (2002). Design research: What we learn when we engage in design. *The Journal of the Learning Sciences, 11*, 105-121.

Falk, J. & Storksdieck, M. (2005). Using the Contextual Model of Learning to Understand Visitor Learning from a Science Center Exhibition. *Science Education 89*, 744-778.

Falk, J.H. & Dierking, L.D. (2000). Learning from Museums. Walnut Creek: AltaMira Press.

Hidi, S. (1990). Interest and its contribution as a mental resource for learning. *Review of Educational Research, 60*, 549-571.

Hooper-Greenhill, E. & Moussouri, T. (2003). *Researching Learning in Museums and Galleries 1990-1999: A Bibliographic Review*. Leicester, UK: University of Leicester.

Juuti, K. & Lavonen, J. (2006). Design-Based Research in Science Education. *Nordina 3*(1), 54-68.

Krapp, A. (2007). An educational–psychological conceptualisation of interest. International *Journal for Educational and Vocational Guidance*, *7*(1), 5-21.

Lavonen, J. Juuti, K., Byman, R., Uitto, A., & Meisalo, V. 2006. Job characteristics found important for their future career choice by ninth grade students. In S. Yoong, M. Ismail, A. Nurulazam, F. Salleh, F.S. Fook, L.C. Sam & M.N.L. Yan (Eds.), *Proceedings of the XII IOSTE SYMPOSIUM: Science and Technology Education in the Service of Humankind, 30 July – 4 August 2006*. School of Educational Studies, Universiti Sains Malaysia, Penang, Malaysia.

Lewalter, D. & Krapp, A. (2004). The role of contextual conditions of vocational education for motivational orientations and emotional experiences. *European Psychologist, 9*, 210-221.

Ramey-Gassert, L., Walberg, H. J. I., & Walberg, H. J. (1994). Reexamining connections: Museums as science learning environments. *Science Education, 78*(4), 345-363.

Ryan, R.M. & Deci, E.L. (2002). An overview of self-determination theory: An organismic-dialectical perspective. In E.L. Deci & R.M. Ryan (Eds.), *Handbook of self-determination research* (pp.3-33). Rochester, NY: The University of Rochester Press.

Schiefele, U. (1991). Interest, learning, and motivation. *Educational Psychologist, 26*, 299-323.

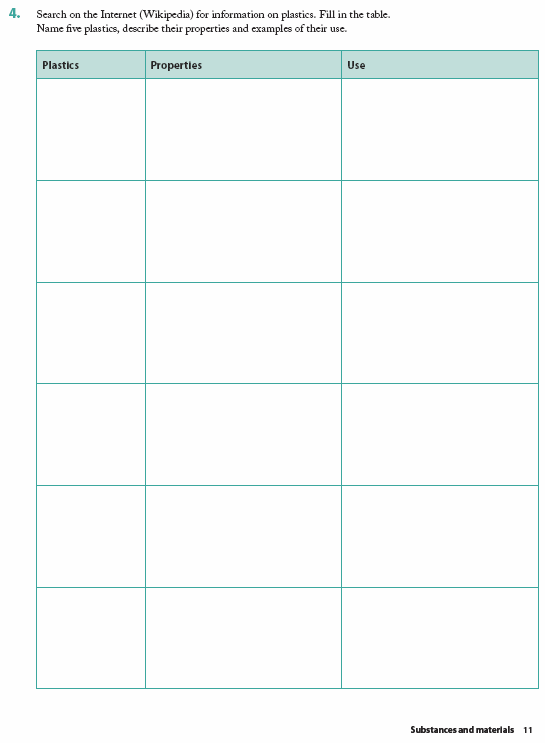
Schraw, G. & Lehman, S. (2001). Situational interest: a review of the literature and directions for future research. *Educational Psychology Review, 13*, 23-52.

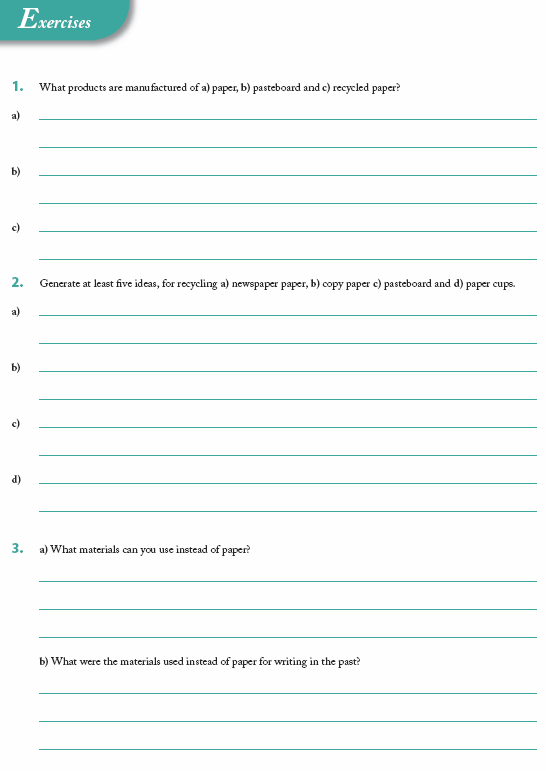
Uitto, A., Juuti, K., Lavonen, J. & Meisalo, V. 2006. Is pupils’ interest in biology related to their out-of-school experiences? *Journal of Biology Education 40* (3), 124-129.

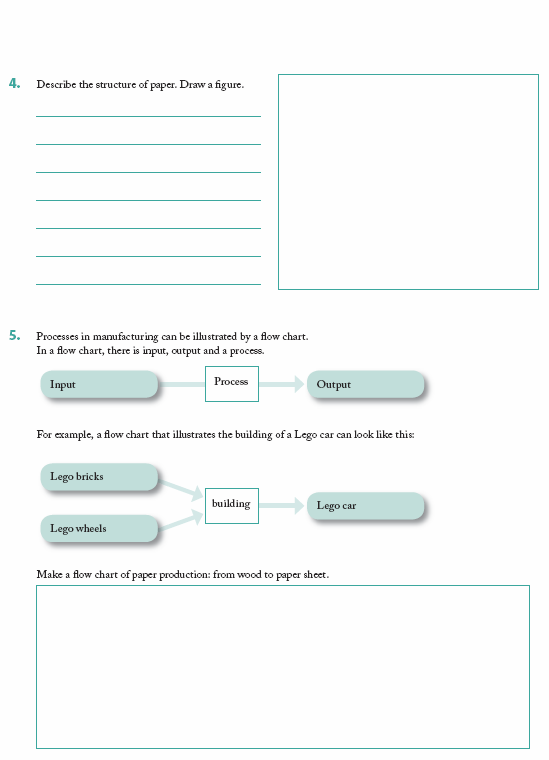
Yin, R. (1994). *Case study research: Design and methods* (2nd ed). Thousand Oaks, CA: Sage.

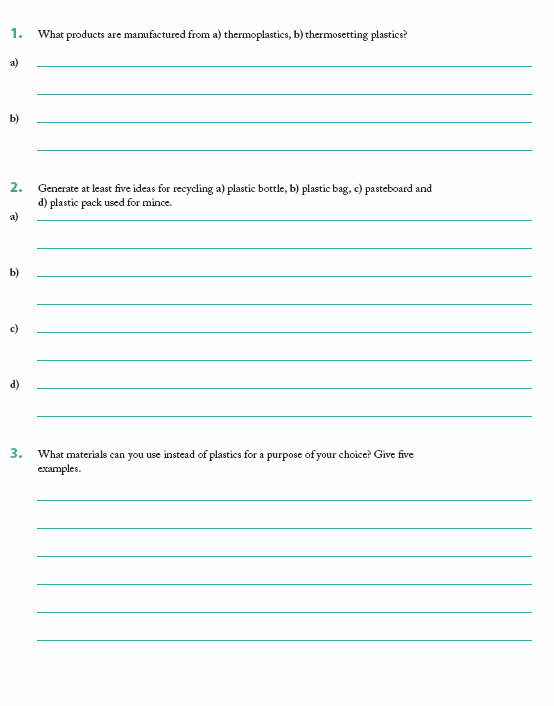
# II. Student Activity Sequence Format

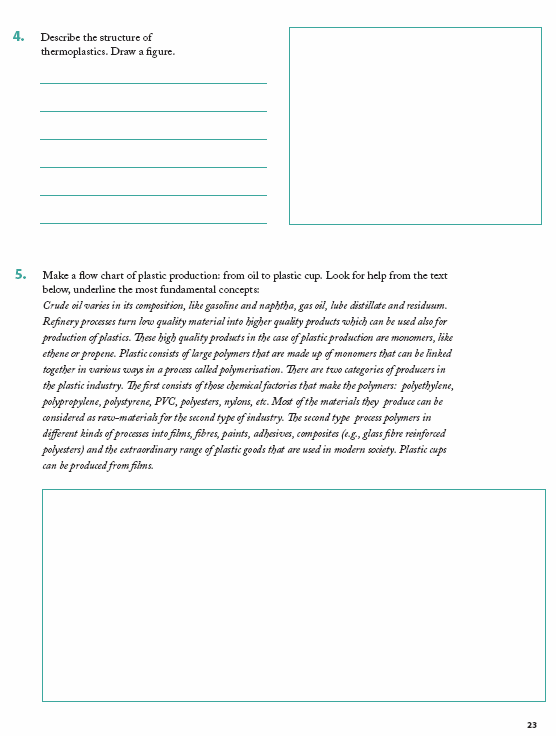
## 1. Paper and pencil worksheets (default option)

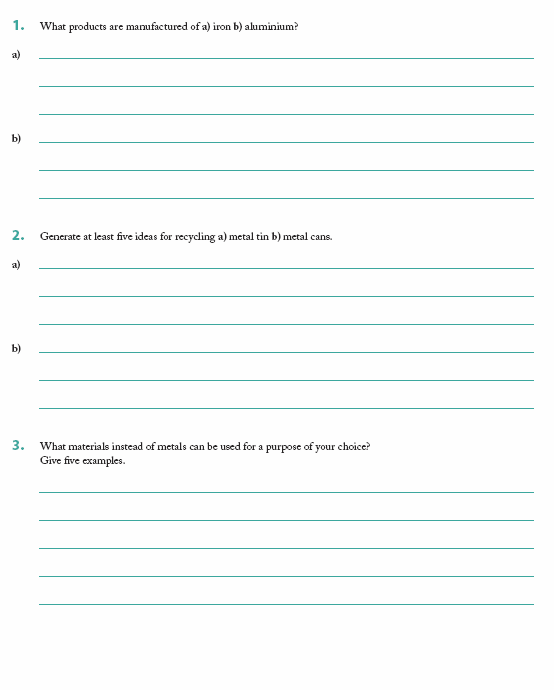
****

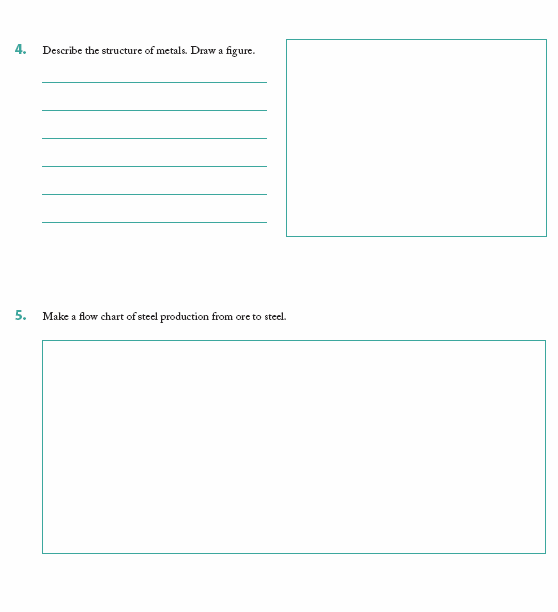
****

****

****

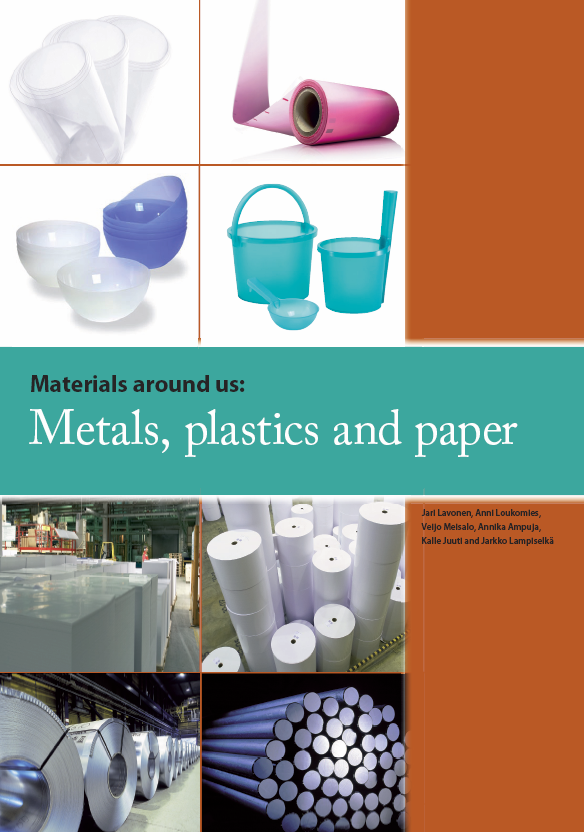
****

****

****

## Student booklet

Loukomies, A. Lavonen, J., Juuti, K., Lampiselkä, J., M eisalo, V., Ampuja, A. & Jansson, J. (2009). *Materials around us: Paper, metal and plastics: Teacher guide*. Helsinki: Economic Information Office. Available in the Internet <http://www.mv.helsinki.fi/home/lavonen/material_science_fin.zip>



1. University-school partnerships for the design and implementation of research-based ICT-enhanced modules on Material Properties, SAS6-CT-2006-042942-Material Science (042942) [↑](#footnote-ref-1)