

## Mineral Examination

*Logot: Heureka, Pencil, Ecsite, EU*

This laboratory programme has been developed at Heureka, the Finnish Science Centre as a deliverable for the Work Package 8: Chemistry for Primary Schools, which is one of the pilot projects of Pencil (Permanent European Resource Centre for Informal Learning, [http://www.xplora.org/ww/en/pub/xplora/nucleus\\_home/pencil.htm](http://www.xplora.org/ww/en/pub/xplora/nucleus_home/pencil.htm) ). Pencil is a European project coordinated by Ecsite (European Network of Science Centres and Museums, <http://www.ecsite.net/new/index.asp> ) and supported by Science and Society, the sixth framework program of the European Community [http://ec.europa.eu/research/science-society/home\\_en.cfm](http://ec.europa.eu/research/science-society/home_en.cfm)

© Heureka, the Finnish Science Centre

[www.heureka.fi](http://www.heureka.fi)

Editor: Kati Tyystjärvi

Layout: Ulla Peltonen

Heureka 2006

## Content

- 1 Teaching observation forms the core of Heureka's laboratory programmes
- 2 Heureka's laboratory programme as part of school work
- 3 The suitability of the Mineral Examination for basic education curricula for grades 1 to 6
- 4 Background to the Mineral Examination programme
- 5 Preliminary work before the Mineral Examination programme
- 6 Carrying out the Mineral Examination programme
- 7 Activities after the Mineral Examination programme
- 8 Links
- 9 Laboratory programmes and their development in Heureka

## 1 Teaching observation forms the core of Heureka's laboratory programmes

Minds that have nothing to confer / Find little to perceive.  
William Wordsworth (1770-1850, English poet)

The scientific process is based on observation and conclusions derived thereof. Observations and the process of observing play a key role in scientific thinking, so it is important to teach observation on a general level alongside factual content.

An observation is the result of the observation process, which takes place in the brain where the data taken in by the senses is processed. An observation is processed data, not just raw data received by the senses.

An observed phenomenon is different to knowledge or the correct answer to a question. An observation can conflict with what has been learned, but it is important to trust one's own observations. Much new scientific knowledge is the result of an unexpected observation and its careful further analysis, see for example [http://nobelprize.org/nobel\\_prizes/medicine/laureates/2005/warren-slides.pdf](http://nobelprize.org/nobel_prizes/medicine/laureates/2005/warren-slides.pdf) and [http://nobelprize.org/nobel\\_prizes/medicine/laureates/2005/marshall-slides.pdf](http://nobelprize.org/nobel_prizes/medicine/laureates/2005/marshall-slides.pdf).

Observations are made through the senses. Humans have five senses: sight, hearing, smell, taste and touch. Phenomena can also be studied with the help of measuring instruments, in which case the measurement results form the basis for observations and conclusions. Observation is subject to many limitations, which include not only physical limitations, but also psychological and cultural differences in observation.

Observation can be taught and one can be trained to observe. Observations based on the senses can be given more meaning by thinking about the power of the senses to separate things. For instance, our sense of sight allows us to observe the colour of the object under our observation, but we can also determine its hue, saturation (dark or light) and luminosity. Our sense of hearing allows us to hear sounds, but we can also distinguish the sound's volume, pitch, tone quality and direction. Our sense of touch allows us not only to feel an object's surface structure, but also its temperature, for instance.

In addition to observation, it is important to teach pupils how to record their observations and inform others about them in a clear manner.

Observation is promoted by the interest the observer feels for the object of study. It is crucial to arouse the curiosity of the pupils in the subject under study. Heureka, the Finnish Science Centre, provides a motivating learning environment (see [http://www.heureka.fi/portal/englanti/about\\_heureka/research/](http://www.heureka.fi/portal/englanti/about_heureka/research/))

## 2 Heureka's laboratory programme as part of school work

### Preliminary work at schools (Chapter 5)

- prepares the pupils in advance for the subject studied at Heureka's laboratory programme.
- teaches the pupils to observe by using their senses and to describe their observations to others.
- teaches pupils to trust their own observations

### Work at Heureka's laboratory (Chapter 6)

- supervised by a guide from Heureka
- carried out in pairs
- pays special attention to observation and methods and equipment in the laboratory

### Linking laboratory work to Heureka's exhibitions (Chapter 7)

- after the work in the laboratory, it is possible to observe phenomena linked to the laboratory programme in the science centre environment.

### Linking laboratory work to the network environment (Chapter 8)

- it is possible to study the subject afterwards and, thus, confirm, deepen and expand the things learned at Heureka.

## 3 The suitability of the Rock examination programme for basic education curricula for grades 1 to 6 in Finland

### Grades 1 to 4: The environment and natural sciences

The programme is linked to the goals set down in the comprehensive school curriculum in that the pupils learn to observe using their senses and simple measuring instruments, as well as learn to describe, compare and classify their observations and conduct simple scientific experiments. The core content in grades 1 to 4 includes the pupils' immediate environment, their home district and its natural environment, as well as substances and materials encountered in everyday life. By the end of grade 4 pupils are able to observe with their different senses and focus their attention on the essential features of the objects, as well as are able to express the information they have learned from the natural environment.

### Grades 5 and 6: Physics and chemistry

The programme is linked to the goals set down in the comprehensive school curriculum in that the pupils learn to conduct simple scientific experiments, which study the properties of objects. The core content in grades 5 and 6 includes classifying materials found in the earth's crust. By the end of grade 6 the pupils are, for instance, familiar with the chemical symbols of some of the elements found in the earth's crust.

Link: Finnish National Board of Education  
<http://www.oph.fi/english/frontpage.asp?path=447>

#### 4 Background to the Rock examination programme

Pupils are usually interested in rocks and many have even collected them. The diverse colours and shapes of rocks are ideal for awakening the pupils' interest in observation and the classification of the materials under study. Furthermore, rocks are important raw materials.

The earth's crust contains many different natural resources that benefit humankind. Among the most valued are the ore minerals, such as iron, titanium, copper, nickel, cobalt and zinc. Along with metallic minerals, the earth's crust is quarried for raw materials that are used as building materials or in the fertiliser and chemical industries. The value of extracting these industrial minerals exceeds the value of extracting metallic minerals. Industrial minerals include limestone, apatite and talc. Mineral rock can also be used as building stone or in jewellery.

Bedrock – rock – mineral?

The earth's crust is comprised of solid bedrock and loose soil. The bedrock is formed from a variety of different types of rock, each of which consists of one or more minerals.

Minerals consist of one or more elements or compounds of such.

A rock type generally consists of several minerals, but a single mineral can also form its own rock type. Granite, for example, is composed of feldspar, quartz and mica.

Based on the way they were created, rocks are classified as igneous rock (formed from melted and solidified magma), sedimentary rock (the result of disintegration, reworking and consolidation) or metamorphic rock (formed through the recrystallisation of existing rocks and minerals, e.g. crystalline slate).

An occurrence is considered to be an ore deposit if it contains a high enough content of one or more ore minerals to make it economically viable for extraction.

## 5 Preliminary work before the Rock examination programme

The following exercises are recommended as an introduction to the Rock examination programme

grades 1 to 4: Collecting and classifying rocks (My own rocks)

grades 5 and 6: Observing materials in the classroom

Rock examination 2.0 en

Preliminary exercises for grades 1 to 4. Teachers' instructions.

### My own rocks

The objective of this preliminary exercise is to make pupils familiar with classifying materials based on the properties that can be observed through the pupils' own senses without the use of instruments. The Rock examination programme classifies materials with the help of field investigation methods used by geologists.

Ask your pupils to bring to class 10 rocks about the size of an eraser. Suggest that they try to find as many different rocks as possible.

In class, the pupils will classify their rocks and arrange them as they wish. You can help them along for instance by discussing together how rocks can be arranged according to size, colour or surface texture. In the end, the pupils will tell each other what their grounds for classification were and how they arranged their rocks. Discuss together the different ways rocks can be sorted!

Rock examination 2.0 en

Preliminary exercises for grades 5 and 6. Teachers' instructions.

### Observing materials in the classroom

The objective of this preliminary exercise is to make the pupils think about different materials and their origin, allowing them to identify those materials in the classroom that are made from minerals. The Rock examination programme makes the pupils familiar with the properties of materials and the ways in which they can be used.

Ask your pupils to write down in one column 10 objects that can be found in the classroom (such as desk, book, eraser, window, wall, curtain, blackboard, sink, hand towel dispenser, pencil). Then ask the pupils to write down the object's main material next to it in a separate column. Next to this, the pupils should write down where the material can be obtained. Ask the pupils to underline the objects that use rock as a raw material.

After the pupils have completed their evaluation, write down on the blackboard all the objects the pupils have thought use rock as raw material.

Rock examination 2.0 en  
Preliminary exercises for grades 5 and 6.  
Pupils' exercise form

Object

Material

Raw material

## 6 CARRYING OUT THE PROGRAMME

### 6.1 The equipment

Rock sample: granite

*Kivi1*

Mineral samples per pair

- grades 1 and 2: quartz, magnetite, iron pyrite

- grades 3 and 4:

- grades 5 and 6: haematite, magnetite, iron pyrite, quartz, muscovite, ilmenite, scheelite, feldspar, chalcopyrite, calcite

*kivi2*

Research equipment

a piece of a mirror

a magnet

a fuse

a conductivity meter

letter scales, a water glass with a scale and a calculator

mild hydrochloric acid and protective goggles

an ultraviolet lamp and protective goggles

Reporting equipment

grades 1 and 3: a form for three minerals +

grades 3 and 4: a form for five minerals

grades 5 and 6: a form for ten minerals

pencil and eraser

### 6.2 IDENTIFYING MINERALS

Many minerals have characteristic properties that can easily be studied. Heureka's mineral study utilises the same types of tools that rock enthusiasts and geologists use when they study the terrain in search of interesting rocks.

#### 1. Lustre

Lustre is the way a mineral reflects light. The lustre can be either metallic or non-metallic. A non-metallic lustre is compared to familiar everyday things and named after the impression the lustre makes on the examiner. A non-metallic lustre can be defined as being glassy, adamantine, silky, pearly, waxy or earthy.

Many ore minerals have a metallic lustre. A greasy or glassy lustre suggests quartz, feldspar or calcite.

Heureka's mineral identification process: The mineral specimens are studied to see whether they have a lustre or not. The observation process is helped along by such questions as: Do all the rocks have the same kind of lustre? How can the lustre best be seen? With what can the lustre be compared? What is the reason for the lustre? With the exception of ilmenite, all of the specimens in this mineral study have lustre, albeit differing. Pure ilmenite does have a metallic lustre, but the secondary ore of iron in ilmenite is oxidised and has a rusty appearance with no lustre. The discussion may lead to further discourse about the different types of mineral lustre.

## 2. Hardness

The hardness of a mineral is quite a distinctive characteristic. Hardness is determined by comparing the minerals to another known mineral or object.

Minerals are divided into ten hardness classes in accordance with the Mohs' Hardness Scale. Each class is represented by an easily identifiable sample mineral. The scale is not uniformly graduated. The absolute hardness distinctions are illustrated by the Rosiwall Scale, which shows the superior hardness of the world's hardest mineral, the diamond: a diamond is 424,242 times harder than talc and 1,166 times harder than quartz.

	Mohs'	Rosiwall	
Easily scratched by fingernail		talc	1 0.33
Scratched by fingernail		gypsum	
2			
Easily scratched by an iron nail/knife	calcite	3	
Scratched by an iron nail/knife	fluorite	4	
Barely scratched by an iron nail/knife	apatite	5	
Mineral mildly scratches glass	feldspar	6	
Mineral easily scratches glass	quartz	7	120
Mineral scratches quartz	topaz	8	
Mineral easily scratches quartz	corundum	9	
Mineral cuts glass	diamond	10	
140 000 (!)			

Heureka's mineral identification process: Mineral samples are defined by whether or not they clearly scratch the surface of a mirror. The observation process is helped along by such questions as: What else can be used to scratch the rock? What differences do the rocks reveal? You have to press down on the minerals quite hard in order to get a reliable result. However, it is not easy to differentiate an obvious streak from a subtler one. This is due to the fact that minerals that are slightly softer than quartz will also scratch a mirror to some extent.

### *Kivi3*

#### 3. Magnetism

Natural magnets, which the Greeks were familiar with as early as 600 B.C., are magnetic iron ores, often magnetites. Their name derives from the name of a town called Magnesia. Today, only artificial magnets have any technical significance. Permanent magnets, such as the rectangular magnet used in this study, are produced from hard materials that are magnetically excited using, for example, strong electromagnets. The oldest of the hard materials is carbon steel, which is often alloyed with manganese and tungsten. Newer hard materials include alloys of aluminium, nickel and cobalt.

Magnetite is easily identified by its magnetism.

Heureka's mineral identification process: Test which minerals are attracted to the magnet. Of the samples given, haematite is also drawn to the magnet, but it never sticks to the magnet in the same way that magnetite does.

#### 4. Colour of mineral powder

The colour of a finely ground mineral is a reliable and frequently used method for identifying ore minerals. The colour of mineral powder is found most easily by scraping the mineral on unglazed porcelain. Ore minerals usually give a black or strongly coloured streak, while gangue minerals (other than ore minerals) leave a white or light coloured streak.

Heureka's mineral identification process: Rub the mineral against the surface of the fuse. A fuse is better than the back of a tile, since a tile is quite a soft ceramic; the white powder that breaks off from the tile is often mistaken by children as having come from the mineral itself. A fuse is a harder ceramic. Note! Quartz is so hard that it does not give off a powder of any colour. On the contrary, it scratches the fuse so that white powder comes off the fuse itself. Participants should also be told that they should be careful with muscovite, because it is so scaly in structure that you cannot get powder from it by rubbing. The third important thing to note concerns the chalcopyrite sample: the mineral contained in the sample appears as yellowish flecks on the surface of the rock and it is these flecks that one should rub on the fuse in order to produce the black powder.

### *Kivi4*

#### 5. Conductivity

Metals conduct electricity; therefore, metalliferous minerals also conduct electricity.

Heureka's mineral identification process: First discuss whether a rock can conduct electricity. What is inside an electric wire? Where does copper come from? Use of the

conductivity meter should be taught step by step. The wires must be held by the plastic insulators and the ends of the wire must touch different places on the rock simultaneously in order to see whether the rock truly conducts electricity.

*Kivi 5*

+ *Kivitutkimusmittarikaavio pdf!!!!*

## 6. Dissolution in hydrochloric acid

Several carbonate minerals dissolve in dilute hydrochloric acid. The easiest to dissolve is calcite (calcium carbonate). The reaction is as follows:  $\text{CaCO}_3 + \text{HCl} \Rightarrow \text{CO}_2 + \text{H}_2\text{O}$ .

Heureka's mineral identification process: The concentration of the hydrochloric acid solution used at Heureka is only 2.5%, but we still require the use of PROTECTIVE GOGGLES for this experiment. What can be observed when hydrochloric acid is dropped on the mineral's surface? Can something be heard? Seen? Only calcite actually dissolves in hydrochloric acid. The visible fizz and hiss given off by the magnetite in our mineral samples is the result of the subordinate mineral in the Kolari ore, which is a skarn ore (converted limestone), calcite. It has small calcite crystals, which cannot necessarily be seen with the naked eye.

*Kivi6*

## 7. Fluorescence

Fluorescence is created when energy is absorbed by a particular substance. The substance then releases the energy or a portion of it as a visible glow or as electromagnetic radiation with a wavelength close to that of visible light. Economically, the most significant of the fluorescent minerals is scheelite, which contains tungsten.

Heureka's mineral identification process: All of the samples are illuminated by an ultraviolet lamp, which reveals the obvious light blue glow of the scheelite. As ultraviolet light is damaging to the eyes, PROTECTIVE GOGGLES must be worn for this activity.

*Kivi7*

## 8. Colour

Many of the ore minerals have a relatively stable colour, but the colour of other types of minerals may vary greatly. For this reason, the colour is not reliable as the sole identifying characteristic.

The observation process is helped along by such questions as: What colours are absent from the rocks? What colours are common in the rocks?

## 9. Weight

Rocks containing ore minerals are often heavier than ordinary rocks. However, since rocks are different sizes, they are difficult to compare. The most obviously 'heavy' mineral is magnetite, whose specific gravity or density is 5 g/cm<sup>3</sup>. The specific gravity of the more common silicate minerals, such as feldspar, varies from 2.5–3.5 g/cm<sup>3</sup>.

Determining the specific gravity: The mineral is weighed as accurately as possible. Then its volume is measured by placing it in a vessel full of water. The amount of water displaced by the rock is measured, which gives the volume of the rock. The weight of the rock is then divided by its volume, which gives its specific gravity.

### 6.3 Minerals used in this study

#### 1 Haematite Fe<sub>2</sub>O<sub>3</sub> (iron oxide)

Lustre: highly metallic. Colour: dark grey with occasional tinge of blue. Not magnetic. Hardness: 5–6. Specific gravity: 5.

The best identifying characteristic of haematite is the reddish-brown, cherry red or even blood red streak, for which it is aptly called the bloodstone. Haematite contains 70% iron, and is the most important of the iron ore minerals.

Red ochre is powdered iron oxide.

#### *Hematiitti*

#### 2. Magnetite Fe<sub>3</sub>O<sub>4</sub> (iron oxide)

Lustre: metallic. Colour: black. Highly magnetic. Streak: black. Hardness: 5.5-6. Specific gravity: 5.

Pure magnetite contains about 72% iron. Two of the world's largest deposits of magnetite are found in Kiirunavaara and Gällivar in Northern Sweden. Finland has had small deposits of iron ore, such as in the Silvola mine in the community of Helsinki during the last century.

#### *Magnetiitti*

#### 3. Iron Pyrite ('Fool's gold') FeS<sub>2</sub> (iron sulphide)

Lustre: metallic. Colour: brassy yellow. Conductive. Streak: black. Hardness: 6–6.5. Specific gravity: 5.

Fool's gold (iron pyrite) is usually found in small cubes. Pyrite is used to produce sulphuric acid. It is the most common sulphide mineral in the earth's crust. Pure pyrite contains 46.7% iron and 53.3% sulphur.

Finland's most notable iron pyrite deposit is the Pyhäsalmi ore, whose precious metals include zinc, copper, silver and gold.

### *Rikkikiisu*

#### 4. Quartz $\text{SiO}_2$ (silicon dioxide)

Lustre: glassy. Colour: wide variation, most commonly white. Hardness: hard, 7. Specific gravity: 2.6.

Quartz is the second most common mineral in the earth's crust, and has many different varieties. Quartz is used for a number of purposes, such as the raw material for porcelain and glass.

Many colour varieties of quartz are used as gemstones. Amethyst is a violet variation, rose quartz is red and smoky quartz is grey or brown. During the Stone Age, quartz was a valuable raw material for tools. Flint is a cryptocrystalline variety of quartz, which is not found naturally in Finland, but is an imported product.

### *Kvartsi*

#### 5. Muscovite $\text{KAl}_2(\text{Si}_3\text{Al})\text{O}_{10}(\text{OH},\text{F})_2$ (potassium aluminium silicate hydroxide fluoride)

Transparent, pale yellowish or brownish mica mineral. The flaky scales can be easily separated using the end of a knife. Hardness: soft, 2.5–3. Specific gravity: 2.7–3.0. Streak: white.

Muscovite is useful for such things as insulators for electrical equipment. In Finland, muscovite is mined as insulating material from the Viitaniemi pegmatite quarry in Orivesi.

### *Muskoviitti*

#### 6. Ilmenite $\text{FeTiO}_3$ (iron titanium oxide)

Lustre: metallic or partially dull, Colour: black. Hardness: 5–6. Density: 4.7. Streak: brownish black. Ilmenite often contains many impurities, most commonly iron, which may be in an oxidised form. The theoretical titanium content is approx. 53%.

Ilmenite is the raw material for titanium dioxide, as well as other titanium products. Titanium is the ninth most common element in the earth's crust.

Titanium dioxide is a white pigment.

### *Ilmeniitti*

#### 7. Scheelite $\text{CaWO}_4$ (calcium tungstate)

Colour: varying shades of greyish white (note: difficult to distinguish from feldspar).  
Streak: white. Hardness: 5. Specific gravity: 6, heavy mineral.

The most important property of scheelite is its fluorescence; scheelite radiates a bright blue light when an ultraviolet lamp shines on it.

Scheelite and calcite are Finland's most common fluorescent minerals.

### *Scheeliitti*

#### 8. Potassium feldspar $\text{KAlSi}_3\text{O}_8$ (potassium aluminium silicate)

Lustre: glassy. Colour: generally reddish, greyish or white. Hardness: 6. Specific gravity: 2.5. It is distinguished by so-called perthite intergrowth: light, curving stripes or veins that are visible on the cleavage plane.

Potassium feldspar is an important raw material for the porcelain and glass industries.

### *Maasälpä*

#### 9. Chalcopyrite $\text{CuFeS}_2$ (copper iron sulphide)

Lustre: metallic. Colour: greenish or brassy yellow. Similar appearance to pyrite. Streak: greenish black. Hardness: quite soft, 3.5–4. Specific gravity: 5. Occurs as masses of isolated crystals.

Chalcopyrite contains about 35% copper, 30% iron and 35% sulphur.

This is Finland's most important copper ore mineral.

### *Kuparikiisu*

#### 10. Calcite $\text{CaCO}_3$ (calcium carbonate)

Lustre: glassy, most commonly white, but also clear or greyish. Hardness: soft, 3. Specific gravity: 2.7.

A fine distinctive characteristic of calcite is its reaction with diluted hydrochloric acid, producing carbon dioxide (as bubbles). The mineral is also distinguished by its ability to be easily cleaved.

Calcite is the primary mineral component in limestone (marble). Calcite-rich limestone is valuable as the raw material in cement production, and in the chemical industry and for other such uses.

Calcite is Finland's most common fluorescent mineral along with scheelite.

*Kalsiitti*

## 7. Activities after the Rock examination programme

We recommend that you visit Heureka's Bedrock Exhibition, which displays 123 chunks of rock arranged by province in the shape of Finland. A list of the rocks is given in the appendix.

Observe rocks using the observation methods you learned in the Rock examination programme, using colour, lustre and hardness, for instance.

You can also get to know rocks by looking for the following qualities:

- building stones *Kivi 10*
- industrial minerals *Kivi11*
- gemstones *Kivi9*

You can also study the Outokumpu exhibition area which tells about copper ore and how copper is made.

*Kivi 8*

## 8. Links

The Geological Survey of Finland (GTK) <http://www.gsf.fi/aineistot/index.htm>

## 9 Laboratory programmes and their development in Heureka

The logo for the PENCIL project, featuring the word "pencil" written in a blue, hand-drawn, lowercase font. The letters are slightly irregular and have a textured, brush-like appearance. A horizontal blue line is drawn underneath the word.

This manuscript has been written in collaboration with 14 European science centres, research institutes and universities in the PENCIL project. The aim of the project was to create the Permanent European Resource Centre for Informal Learning.

Heureka's original exhibition plan did not include laboratory facilities or supervised laboratory activities. However, in 1989, in the summer following Heureka's opening, a space was arranged in the Pillared Hall for demonstrations and activities to illustrate the study of natural waters in a water laboratory. This science theatre and laboratory rolled into one was used until 1992, when the glass-walled space in the Cylinder Hall was converted into the Children's Laboratory. The first programmes were Basic Chemistry I and II, the first of which evolved to the present Bubbling chemistry programme. The laboratory facilities were modernised when the main exhibition was renewed in 1999 and another laboratory was built to meet the increasing demand.

The purpose of the laboratory programmes is to create interest in the natural sciences and the empirical scientific method, make laboratory work familiar to children and illustrate the importance of co-operation (working in pairs) in scientific work. There have been numerous programmes throughout the years. They have been jointly developed by Heureka's guides, usually on the basis of a preliminary manuscript written by one of the guides. Programmes have also been developed on the basis of activities created for science camps held in the summer.

The programmes and the authors of the original manuscripts:

Bubbling chemistry (originally Basic chemistry I): Paula Löfman designed the programme as the first activity in the Children's Laboratory in 1992. The final version has evolved through the work of Heureka's guides.

Colourful chemistry (originally The making of a Red cabbage indicator): Anni Fast for the 2001 science camp, final version by Kati Tyystjärvi and Heureka's guides.

Rock examination: Merja Nuutinen and Paula Löfman 1992. Originally a laboratory programme designed for the measuring station. Final version by Kati Tyystjärvi and Heureka's guides.

Water analysis: Kati Tyystjärvi 1989, originally piloted in 1986 in the AQUA 86 pilot exhibition. Final version by Kati Tyystjärvi and Heureka's guides.

From large to small: A combination of two programmes: Extracting DNA (original programme for Heureka by Risto Poijärvi 1998) and Cell adventure (Jutta Kujasalo for the 2005 science camp). Final version by Kati Tyystjärvi.

The equipment for all the programmes was standardised in conjunction with the renewal of the main exhibition in 1999. The manuscripts were also standardised so that they contained all the necessary information the guides need to carry out the programme.

The PENCIL project began in autumn 2004. In Heureka, the project is headed by Professor Hannu Salmi, Dalarna Universitet, Head of Research and Development, Heureka. The manuscripts of the laboratory programmes have been edited by Kati Tyystjärvi, M.Sc. (Agr. & For.), Senior Exhibition Co-ordinator. The work has benefited from the expertise and ideas of Heureka's guides and Ning Zhang's 2005 Master thesis in Science Communication, University of Dalarna, Sweden: Science is Primary. Children Thinking and Learning in the Chemistry Laboratory.