1. Title & Notes

History of Cooling Technology, Ice Production

2. Authors & Institutions

Veronika Maiseyenka, Andreas Henke (University of Bremen), Anna Launus (University of Oldenburg), Falk Rieß (University of Oldenburg), Dietmar Höttecke (University of Hamburg) Germany

3. Short Version

This present teaching unit was developed for sixth graders. The material touches the topic of thermodynamics and the field of temperature; heat and thermal conduction; insulation and good/bad insulators; aggregate phase; and its changes (melting, congealing, and boiling); melting and boiling temperature; freezing point and also vaporization becomes accessible.

These topics are embedded in the historical context of the development of refrigeration technologies and ice production. Above all, this development is particularly characterized by techniques of the realm of experience like cooling by evaporation. The material deals with food storage in Ice Houses, usage of freezing mixtures, the spreading of domestic cooling technology with refrigerators and the development and utilization of modern refrigerating machines.

One of the core aims of this teaching unit is the extraction of thematic content-related competencies as well as methodical cognition. Pupils are to acquire an elementary knowledge in experimental work and theoretical material. Through guided scientific activity in class, and by reflecting on scientific theoretical questions specifically, pupils are supposed to learn historical context and scientific ways of working and thinking.

4. Description

The necessity to store food has existed among Man since a long time. Thus various cultural techniques developed like drying, smoking, high heating, alcoholic fermentation, application of great amounts of sugar (to candy) or salt (to pickle), and other methods of food conservation.

A special technique however is cooling, which slows down the decomposition by micro organisms or stops them altogether and thus leaves food in its original condition. Ice and snow in those times were best suited and more or less available dependent on region and season.

In cold northern regions or at high altitudes cooling was naturally easier. People were able to make use of frozen water over longer periods and stored ice well insulated in deep cold pits throughout whole periods of spring and summer months, and allowing it to slowly deplete.

In the south, ice and its potential for cooling were a treasured luxury, accessible only for a few people. Ice or snow and their purchase were very complicated and products were therefore expensive. Food, beverage and space cooling by potentates were more popular in southern regions. The first forms of our ice cream, ice mixed with milk, wine, spices, fruits and fruit juices, were a sign of wealth for a long time. Sometimes servants would pay with their lives for making mistakes or by failing to keep ice cream recipes secret. The fascinating story of ice cream is part of our lives already, from the ancient Chinese until today, and is directly connected with the history of the development of cooling technologies.

Nowadays a life without refrigeration and our leisure time without ice cream can hardly be imagined. But how did humanity come to such an important invention in today's world? Has it been a sudden overnight discovery, or did people do a lot of research before it was attained? How exactly, was food kept cool before the age of refrigerators? Did early people also enjoy ice cream? Were they able to cool well enough to produce ice cream from milk or cream? How is ice cream actually prepared? Is it different today than in earlier times? What does this kind of history have to do with science? How do scientists actually work and where are they taking their questions from?

Pupils may find answers to these kinds of questions in this teaching unit. This work is based on:

- processing of informative material (partly through play) and its analysis,
- projecting and reconstructing of own models of historical cooling- and ice production techniques,
- planning of own experiments in order to examine their hypotheses
- analysis of own approaches in research and their reflection in the context of scientific work.

Learning in this teaching unit is organized in the form of a learning circle (carousel). Ten 'stations' are developed, dividing the whole issue into three blocks.

Block 1: History of Cooling: Life Without Refrigerator:

Station 1: Life without Refrigerator

Station 2: Cooling by Evaporation

Station 5: Ice House

Station 7: Freezing Mixture

Block 2: Refrigerator: History and Present:

Station 3: Pot-in-Pot Fridge

Station 4: Modern Refrigerator

Station 6: Fridge

Block 3: Ice Production: Past and Present:

Station 8: Snow, Fruits and Honey

Station 9: First Revolution in Ice Production: Freezing Mixtures

Station 10: Second Revolution in Ice Production: Refrigerating Machines

Students can work in small groups of up to three pupils at these stations. The ideal working condition would be keeping the sequence of the stations, as they appear in the blocks. Since this is difficult to realize considering time and organization, it will be good for each group to work at least at one of the stations of each block. The order is optional.

Some of the topics in the different blocks have common physical contents in spite of different contexts. Examples of this are Station 2: "Cooling by Evaporation", Station 3, "Pot-in-Pot Fridge" and Station 9, "First Revolution in Ice Production: Freezing Mixtures". For this reason the teachers should be aware that their student groups preferably occupy stations from different blocks that have different key physical aspects. In section 3.1 the stations are described in more detail. This way, ideal combinations can be defined for precognition and abilities of pupils.

4.1. Short description *of Stations*

Station 1: Life without Refrigerator

Students assign possible purposes to a tabular overview of the individual stations in the history of cooling. Thus they are learning the development of cooling options.

Afterwards they are to imagine themselves being in a situation without modern cooling technology, and to create a story on how they would do the cooling in that case.

In a brief text they will be informed about nature-oriented possibilities of cooling. They are to develop a cooling setup with the materials provided.

Station 2: Evaporative Cooling

Pupils will receive information about evaporative cooling. In a small experiment they are to experience for themselves how cooling by evaporation works. Afterwards, on the basis of their newly gained knowledge they are to develop, conduct, and explain an experiment on the identification of wind direction.

Finally the pupils are to imagine being scientists themselves and to develop experiments in order to determine the influence of factors on vaporescence (wind, type of fluid, evaporative surface). Pupils perform these experiments independently with available materials.

Station 3: "Pot-in-Pot Fridge"

The Station starts with brief information about the problems that occur in southern regions of Africa without the possibility of cooling foods.

Pupils will discover a possible solution for this calamity by the development of the "pot in pot fridge". On the basis of this information pupils are to develop experiments to examine the factors which influence temperature and thus the quality of cooling. Pupils perform the experiments with provided materials.

In their next task they will have to explain the principle of a "miniature fridge" from India on the basis of their gained knowledge.

Finally pupils are to reflect in a concrete context the development of this "pot-in-pot fridge" and explain what they think to be scientific compared to their own approach. Moreover they are to state the causes that induced Bah Abba in his research, and to discuss possible generalizations.

Station 4: Modern Refrigerator

Station 4 is directly connected to the work on Station 3, because pupils are confronted with possible causes for the advancement of the development of cooling techniques. In a chart they mark what they think to be the driving factors and motives for progress. As a conclusion they are to write a brief comment.

The next three tasks will be about collecting data for a temperature curve for the boiling heat transfer and to analyze it phenomenologically. Pupils are to work out the differences between heating on a hot surface and heating in a 200° degree baking oven.

In the following experiment students are to look into the subject of sensation of temperature and the concept of the boiling point, or rather ebullition. They discover with the example of liquid nitrogen that not everything that boils necessarily needs to be hot.

Continuing with a short introduction about the principle of cooling by liquefaction by air (Linde method), pupils are to apply their acquired knowledge in an exercise.

In closing pupils receive information on the further development and optimization of modern refrigerators, didactically adapted by a newspaper article on a "refrigerator accident" (cooling liquid discharge). Pupils are to reflect on how far scientists are responsible for the potential consequences of their findings.

Station 5: Ice House

Pupils receive information about natural ice storage. Then they are to independently examine the best way to store ice using the materials provided. They will write a kind of research report in which they document strategies, variants, challenges, observations and results. Finally they are to draft a short manual for the construction of a cold store (with layout and construction plan). Furthermore they reflect upon the relevance of documentation of research processes and on the relationship between the areas of science and technology. Afterwards they receive information about historical natural ice production/mining. Given single pictures they are to formulate research questions and comment on why scientists would want to research these.

Station 6: Fridge

Pupils receive information on fridges, the prototype of refrigerators. On the basis of the available information they are to answer questions about the fridge. Above all, the main issue is to understand the function of each construction element of the fridge. These serve as a context for the phenomena of air circulation. Afterwards they are to reflect critically upon the expenditure of time related to this cooling technology. Finally pupils are to construct (with drawing) a model of a fridge with available materials.

Station 7: Freezing Mixture

Initially the pupils are confronted with the notion that sanding the road is supposed to help guard against slipping on glazed frost caused by melting ice and snow. This contradicts to what they will learn next through experiments: that the addition of salt would lead to warming and thus to melting of the ice. They are to measure temperatures in order to experience the effects of lowering the freezing point.

Afterwards they will be given information on how people used to cool with ice and salt mixtures in the days when cooling machines did not yet exist. Pupils are to independently conduct a series of tests, guided by the problem that salt was hard to provide in those days and thus very expensive. The aim is the most effective ice-salt mixture; that is, the best possible cooling using the least amount of salt. In conclusion, they are to defend their results in a letter to the editor.

Station 8: Snow, Fruits and Honey

Pupils receive a short introduction into the history of ice cream. First they are to put information into chronological order. Subsequent to that, the students perform an experiment on the thermal conductivity of various materials (wood, plastic, metal, etc.), by heating spoons through these materials and qualitatively evaluating their observations. Pupils are to apply their knowledge about thermal conductivity after that with a concrete example.

Station 9: First Revolution in Ice Production: Freezing Mixtures

Pupils learn about the history of ice production using freezing mixtures. They are to read a brief selection of phases in the development of ice production and on the basis of this story reflect upon how everyday knowledge becomes scientific knowledge.

After a historical description of ice cream production in 1803, pupils are to make their own ice cream using freezing mixtures. Pupils are asked to think about the scientific background behind this event.

Station 10: Second Revolution in Ice Production: Refrigerating Machines

Pupils will comprehend the construction and operation of historical ice cream production in a double-walled container that uses freezing mixtures as cooling device. Which are the functioning parts of a historical ice cream machine? Why is the inner wall made from iron? Why should one turn the can really fast? On this basis they are to design their own ice-machine and draw its layout. The transfer from cooling with ice-salt-mixtures has to become clear in this venue, and modern and historical technologies are to be compared.

5. Background

5.1. Cooling Technology and Ice Production – Historical Steps (approximate):

Cooling using…	Time	Purpose
Natural Ice – Artificial Ice		
1) natural ice + cool room/store	1200 B.C. in China across the Orient to Europe until 1950	storage of foods, cooling of beverages
2) natural ice and artificial ice + fridge	end of 19th century until 1950	
Cooling Mixtures		

nitrate with water (fluid cooling mixtures)	ca. 1550 in Europe, about 300 years before in Arabian countries verifiable from 1150 B.C. in China (probably much earlier)	cooling of beverages
nitrate with snow or ice	Italy since ca. 1530	cooling or rather freezing of aliphatic meals
Evaporative Cooling		
cooling by evaporation	no definite time	unvarnished, unglazed porous pottery vessels used as cooling devices
cooling machines	from 1876 Carl von Linde	cooling, freezing, production of artificial ice, liquefaction of gases etc.

The **history of ice production** goes hand in hand with the history of cooling device development:

Country	**Where? When? What?**
China	Ice cream made from snow with fruits and milk (1-3 century B.C.) The ice was stored in cavernous and freezing Ice Houses.
Ancient Greece	Hippocrates, Alexander the Great (around 300 B.C.): natural ice and snow to eat, for healing and cheering.
Roman Empire	Nero the Emperor (37 until 68 A.D.) ate natural ice and snow as a particular dessert.
Europe: Middle Ages	Marco Polo (around 1300): brought ice cream recipes from ancient China to Venice (and presumably also the idea of freezing mixtures). Catherine de Medici; her ice cream maker and ice cream recipes are state secrets; ice cream belongs to the rich, because its purchase and storage is very costly.
Italy: - first revolution of ice cream production:	Ca. 1530 discovery of the cooling effect of salt-snow mixture and its usage in ice cream; Spreading of improved thermometers make measuring of temperature possible; French scientist, physicist and zoologist René-Antoine de Réaumur (1683-1757) found out that stirring ice cream while cooling also gave a better consistency and taste.
America 1843	first mechanical ice machines, patented by Nancy Johnson
Germany: second revolution of ice cream production 1876	Invention of cooling machine by Carl von Linde – ice cream becomes a mass product. Refrigerating machines substitute for freezing mixtures in ice cream production.

5.2. History of Cooling Technology and Ice Cream Production (fine):

5.2.1. Cooling Technology

1. Evaporation Chill

For an indeterminably long time, Indians and Egyptians used the concurrence of chilling by evaporation chill and radiation of heat by putting water in flat, porous, earthen pans onto a pad of dry straw into small earth dens during very clear and calm windless nights. The water often cools down to freezing point before sunrise but does not always create a layer of ice.

2. Natural Ice

1) In winter when the waters were frozen water ice was "harvested". With the natural ice and the snow from the lakes and glaciers one used to cool food since long time ago (e.g. around 1200 B.C. in China).

2) **Ice House**

For thousands of years people in China used to store the obtained natural ice and glacier snow in especially deep and cold caves and Ice Houses.

The ice had to be strong enough for it (surely more than 20 cm) in order to be able to walk across it without danger. That was when the "ice harvest" began for the earth or Ice Houses. Every year when the ice reached a maximum of 18-20 cm, large ice sheets were cut out of the ice with hoes and saws and pulled with ice hooks to the shores on prepared snow lanes.

The sheets were set up in a vertical position so melting water and dirt could run down. After two days the sheets were kicked over, smashed into portable pieces of about 20 to 25 kg weight, loaded by hand onto horse carriages, and transported to the cold stores.

Upon arrival at the Ice House or earth store the ice blocks were unloaded and brought into the available Ice Houses. Particularly in America they had so called ice houses near the lakes where ice was stored for the summer. Here, as well as in the Ice Houses, insulation was of utmost importance.

The ice was used throughout the year as necessary. The ice stock lasted for a long period and thus kept food cool throughout the whole year.

Images: fig. 1, 2, 3.

3) **Fridges**

Up until around 1950 they also used wooden fridges. They were filled with ice from factories and lakes (stored in Ice Houses). They contained a vessel inside that was filled with chopped ice. The dripping water was collected in bowls underneath. Around the chamber in the middle there were compartments that held the reefer cargo and that were closed with doors.

In spite of the disadvantages of fridges (high price for ice, constant renewal of ice, much work with the melt water and the cleaning of the cabinet) they were only gradually substituted by first refrigerators which took up a lot of space initially, and were very noisy, dangerous and also too expensive.

Images: fig. 4, 5.

3. Artificial Cold

1) Natural Ice was very expensive and available only dependent on the season. Although it was used until mid-19th century as a coolant almost everywhere, people tried very early to produce ice (or cold) themselves:

> Thus, for example in the Middle Ages the cold mixture of nitric acid with water became known. 'With this technique the temperature drops to –15 °C or more. This technique was used until the end of the 19th century.

Mid-19th Century: attempts were made to create artificial ice, and also to develop direct cooling chillers. The impetus for this was particularly high in Central Europe where there were few natural ice sources by comparison to America, which had many sources.
Some boundary conditions of the research:

Especially in England, the growth of population in the course of industrialization caused major nutritional problems. Using cooling technology, one was able to transport cheap food from the colonies.

In Australia, New Zealand and South America there was also great interest in selling the surplus of cattle and sheep to England. But 8 kg of ice was required for every kg of meat to be transported. The transportation problem could therefore only be solved with the help of newly developed chillers.

In 1880 Lord Kelvin constructed a refrigerated ship for the transport of meat from Sydney to London. In addition, he developed a cold engine, where ethyl ether was used as a coolant. But in those first cold ethyl ether machines explosions often burst through its outlet and it caused serious accidents.

A solution to this problem was invented by two Swedish engineering students, Baltazar von Platen and Carl Munters. They developed the method of producing refrigeration by changing the physical states of ammonia.

Image: fig. 6.

2) Artificial Ice

In 1876 the German engineer Carl von Linde introduced his first refrigeration machine. It was characterized by a high degree of reliability and good efficiency.

Carl von Linde was an engineering professor from Munich. His work aroused the interest of the brewing industry, which was in search of new cooling techniques. Natural ice and rock basements were not enough for the growing production any longer. Around 1876 Linde built the first cooling machine for the Munich Spaten Brewery.

Cooling technology was also the basic requirement for equipment Linde used for liquefying air and resolve it into its components.

Even today refrigerators operate like Linde´s fridges: a refrigerant, such as an easy-to-be-liquefied gas is heated by compression and cooled back down at room temperature. Then, the compressed refrigerant is cooled significantly through expansion clearly below the initial temperature (see below). With these new chillers it was possible to produce artificial ice independent of the season.

Images: fig. 7, 8.

4. Chillers - Cooling without Ice and Cold Mixture (Refrigerator):

Cooling circuit in a modern compressor refrigerator:

1) Condenser (condenser, rear warm side of the refrigerator, high pressure, heat is released to the environment),
2) Choke (coolant liquid, low pressure),
3) Evaporator (cold side of the refrigerator - the refrigerator's interior, low pressure),
4) Compressor (liquefaction of the gaseous refrigerant)

Image: fig. 9.

Physical Principles:

Evaporation removes heat (sweating has the same effect): the coolant evaporates because of the pressure drop in the choke (2) and ends up inside the refrigerator. Then this evaporating liquid gathers heat from the refrigerator (3).

Then, behind the refrigerator, it will be compressed by the compressor (4), becomes liquid in the process and returns the heat to the outside again (1).
The procedure is called "The Linde process”. By using this method, Linde succeeded also

in making air liquid at -189 ° C. Under this temperature, the air is liquid, but above it is gaseous. (-189 ° C is therefore called the "boiling point" of air).

Correction of a popular misconception:

A refrigerator does not transport the cold to the inside, but the heat to the outside. Coolants, which were used in refrigerators, have also undergone an evolution. Ethyl ether or ammonia, which were first used in refrigeration, were particularly dangerous when exiting. The CFCs coolants (chlorofluorocarbons) which were used until recently in modern refrigerators have proven to be ecologically very worrisome, because they contribute greatly to Ozone depletion. Today we use environment-friendly coolants in modern refrigerators.

Image: fig. 10.

5.2.2. Ice Cream Production

Modern ice cream is created with the development of artificial refrigeration.

1. Ancient China

Even before 2000 BC the Chinese produced ice.
Even then, one already used ice rooms used for storage during the summer months. They were filled with natural ice in the winter months, from which ice cream could then be produced in the summer. The recipes were very simple and consisted of scraped ice mixed with milk or fruit juices.

2. Ancient Greece

300 years BC, the **physician and scholar Hippocrates** (460-370 BC), according to whom all medicals even today take their professional oath, taught his medical school students the special effect of ice on people: it was said to animate the life juices and improve welfare.

During his conquest, **Alexander the Great** (356-323 BC) had snow mixed with wine, milk, fruit juice or honey for refreshment. After he had accidentally found preserved snow in the mountains in earth pits, he took over this stock method and used it systematically. In this way, snow and ice was available all year-round for the first time.

3. Roman Empire

52 AD. It is said that the Roman emperor Nero (37 to 68 after BC), had ordered special relay runners between Rome and the nearby Alban hills to be able to offer his pampered guests iced dessert made of snow, rose water, honey and fruits.

In the hot season natural ice and snow were also kept as before in special ice cellars. After the fall of the Roman Empire, this original knowledge of preparation and storage of chilled foods vanishes in Europe for a long time.

Images: fig. 11, 12, 13.

The ice cream of those days could not be compared to our ice cream today, for milk and cream could not freeze. Water freezes at 0 ° C. Milk and cream contain fat and congeal only at about -15 ° C. It is believed, however, that the Chinese were already able to freeze dairy products about 1400 years ago (see below).

4. Europe (Italy):

13th Century: It was only centuries later that ice cream again entered into the consciousness of courtly and patrician circles. The Venetian merchant and explorer, **Marco Polo** (1254-1324) reports of previously unknown ice desserts in China, Central Asia, and the Middle East.

In 1292 Marco Polo reported in Venice that the Chinese had known for more than 3 millennia the pleasures and the production of ice cream. He brought back a recipe for making ice as a gift of the Mongol prince Kublai Khan. In his time in China (around 1270) it was already normal that ice was offered in the street shops of China during the summer.

Images: fig. 14, 15, 16.

16th century: In 1530 an Italian confectioner from Catania generated the artificial cold by using his knowledge of the effect of potassium nitrate.

This made their confections independent of the season and ice cream could be produced with moderate technical effort. The fame of this new specialty quickly spread. A dessert made from frozen fruit was a big sensation and was served in 1533 on the occasion of the marriage of the Florentine princess Catherine de Medici with the future French king Henry II.

In 1626 a certain Santoro achieved the same result by mixing common salt and snow in a ratio of 1 to 3.

So from the 16th Century, and for many more centuries, crushed ice with the addition of salt or saltpetre salt in different proportions was the only system for preservation of artificial cooling, and thus for the production and preservation of ice cream.

The French physicist and naturalist René-Antoine de **Réaumur** (1683-1757) discovered that if you constantly move ice during cooling, it becomes much smoother and tastier.

Ice production remained manual until the first decades of the 19th Century.

Images: fig. 17, 18.

5. America: First Ice Maker

The ice machine was first invented in **1843** by the American housewife Nancy Johnson and later was patented. It was a hand-operated ice machine that was a kind of churn, which was cooled from outside by a layer of ice and salt. A smaller pot was placed inside, and, in the gap, salt and snow was scattered. The mixture gets very cold, and a thin layer of milk freezes on the wall of the inner pot. A rotating paddle wheel scratches off this layer, so that a new ice milk layer can form.

Germany: first safe refrigerating machine (chiller)

19th century: Finally, in the 19th century, in the wake of technological innovations, industrial ice cream starts. In 1876 Carl Linde invents the ammonia chiller, which replaces the natural ice and saltpetre salt in the production of artificial refrigeration. With this progress in refrigeration technology, ice cream definitely turns into a consumer good for a broader public.

1905-1906: Ice cream production is electrified.

6. Modern Ice Makers

As in refrigerators (see above), heat is removed from the ice via a refrigerant such as ammonia. The heart of the ice machine is a double-walled cylinder. Between its walls there is the evaporating refrigerant and in the interior is the mixture of ingredients for the ice cream. The ammonia evaporates and thus removes heat from the inner cylinder. The frozen ice on the cylinder wall is scraped off by a stirrer.

Freezing Mixture:
Advantage: not much work is needed, it responds by itself
Disadvantage: the cold mixture is "finite"
Refrigerating Machines with Refrigerant:
Disadvantage: work is needed to ensure that the coolant is brought back again and again from the gas form into the liquid form.
Advantage: the refrigerant remains an undiminished coolant for the use over a long period.

5.3 Learning about the Nature of Science

The affiliation to social and cultural sciences is evident in the combination of work and the study of low-temperature region (and with the aid of low temperatures) with economic interests and with the personalities of individual researchers (e.g. by Carl von Linde). The use of the "working" principle of evaporative cooling in the Nigerian pot-in-pot refrigerators, introduced by a local "scholar" (Bah Abba), changes the life of farmers in the whole region.

From the mid-19th Century, intensive research in different countries in the direction of new, stable, secure and powerful cooling systems has been carried out to ensure, among other things, food shipping to Europe from Australia and South America.

Carl von Linde who was appointed professor of Mechanical Engineering in the Polytechnic School in Munich in 1872, also included the theory of refrigeration machines in his curriculum. This way he could give his students practical lessons, and the Bavarian government granted him 70,000 guilders for setting up a machine laboratory - the first of its kind in Germany. It would become the starting point for his pioneering developments in refrigeration technology.

Such examples make clear the purposefulness of research. Technical requirements definitely stimulate scientific work in the desired direction. Science itself also benefits from the development of refrigeration, because liquefaction of air and other gases made low temperatures attainable. On the one hand, the ice production benefited from the new procedures and new technology that became a whole industry of ice cream production and is accessible to a broad public. On the other hand, the development of refrigerating machines which were now able to produce clean and hygienic artificial ice caused the collapse of another powerful industry – the natural ice trade.

Refrigerators and freezers were "born". Their cooling solvents often caused health and environmental problems and led the scientists to search for new, safer chemical substances. The preliminary nature of knowledge becomes evident in such examples.

These facts also illustrate the erratic nature of knowledge development. Cooling with frigorific mixtures and refrigeration of very low temperatures were extremely important events in both the scientific and in the economic world. In order to highlight their importance these events have been referred to as the "first" and “second” revolution in the making of ice cream. in the illustrated history of development. The invention of electric motors contributed momentum to ice cream production because ice no longer needed to be mixed "by hand". The electric motor took over the strenuous work by the paddle wheel drive in the freezer box.

Freezing mixtures were one of the main cooling methods for centuries and have been mentioned in scientific literature as early as 1550. Cooling with water, salt or the ice-salt mixture was probably known and widely used much earlier. People used the phenomenon of the cooling effect of freezing mixtures much earlier than the scientific knowledge about the phenomenon was probably known and widely used. Not only Italian ice cream makers, but also physicists made use of this type of cooling. Daniel Gabriel Fahrenheit (1701-1744) used water-ice-ammonium chloride to set the zero point to graduate his thermometer when he was experimenting with thermoscopes in the period from 1710 to 1720.

What is the best way to find the best ice-salt ratio for cooling? Experimentation is a strategy to acquire knowledge and students learn through hands-on experience with the teaching material provided.

How do scientists experiment? How do they acquire new knowledge? How do they go about it? Students will ask such questions about the nature of science in the course of the work in this teaching unit. The analysis of their own research activities will help them to answer these questions.

6. Subject specific Learning, Didactic Advantages

6.1 Technical Contents, Basic Concepts, Learner Conditions, Educational Standards

Thermodynamics is the basis of this teaching unit. No subject specific premises are required from the students. Everyday experiences of thermodynamic phenomena which students bring into the classroom build a basis for further training of thermodynamic perception on a phenomenological basis. Emphasis is put on the research activity in a technical and scientific context for students. Special significance is given to experiment planning, observation and results that refer back to the research questions. The tasks to be processed usually have a teaching effect. All necessary technical information is given in the assignments or is acquired with the help of the experiments. Students are encouraged to use this content in planning the experiments and through reasoning that supports active and autonomous learning in a constructivist sense.

Subject-specific Contents:

Cooling by evaporation: fluids cool off when evaporating; speed and power of evaporation depends on such parameters as type of liquid, wind, liquid surface; applying the principle of evaporative cooling in "simple" cooling systems.

Changes in water temperature while heating and cooking; water boiling at a higher and a lower outdoor temperature; boiling point of water; nitrogen and air; operation of a compression refrigerator (the Linde process) in four stages.

Heat conduction, heat insulation; good / bad insulators; technical application of the insulation.

Freezing mixtures and technical application of cold mixtures.

Basic Concepts: Energy (Physics), Energy in Chemical Transformations (Chemistry).

Established Skills: process of gaining knowledge; especially experimental skills (setting up hypothesis; developing questions; planning and carrying out an experiment; following instructions; observing and measuring; installing and implementing documentation; referring back the results to the question or hypothesis.

6.2. Teaching / Learning Objectives

Station 1: Life before the Fridge

Students are to learn important steps about the history of cooling.

Students are to develop ideas, with driving factors that could be relevant for the further development of cooling technology.

Students should independently plan and draft test executions;

Nature of Science (NoS):

Students should understand that research and technological development can be motivated by everyday needs.

Students are to highlight differences between the experimental possibilities in the physics classroom and laboratory and everyday life and give subject-specific reasons.

Station 2: Cooling by Evaporation

Students are to work out and use technical information about evaporation of liquids from the material provided.

Students should be able to name the factors influencing evaporation (surface, substance).

Students should independently plan to carry out experiments on the basis of acquired knowledge.

Students should identify the connection between a given phenomenon / trial and the information material.

Students should document their attempts.

Results of student observations should refer back to the given research questions.

Station 3: "Pot-in-Pot" Fridge

Students should independently filter out the necessary information from the provided written materials.

Students should see the connection between a given phenomenon / trial and the information material.

Students are to investigate factors influencing the quality of the cooling method with the "pot-in-pot" fridge (shape / surface of the pots, water-sand mixture).

Students should independently plan and conduct experiments on the basis of the acquired knowledge.

Students are to establish presumptions.

Students should discuss their own ideas with their classmates.

NoS:

Students should realize that in science they are dealing with processes that are influenced by numerous factors (for example social needs).

Students should address the issue of scientific method in certain approaches.

Students should think about the reasons for scientific research.

Station 4: Modern Refrigerator

Students are to carry out experiments independently under instruction and record their observations and results using appropriate terminology.

Students should differentiate between the term "boiling" (purely phenomenological) and the term "cooking" (transition liquid to gas).

Students are to phenomenologically describe the constancy of the boiling temperature.

Students should be able to explain that the boiling process does not have to be associated with high temperatures (example nitrogen and other gases which are gaseous at room temperature).

Students should be able to use the term "*boiling point*" correctly as a component of technical language.

Students should be able to reflect the essence of the Linde process.

Students are to explain the cooling in the refrigerator through the transporting of heat (rather than production of cold).

Students should understand the principle of the cooling cycle as supply and removal of heat.

NoS:

Students should realize that research is influenced by various factors.

Students should be made aware of the interactions between technology and science.

Station 5: Ice House

Students should be able to use the term "insulation" correctly as a component of technical language.

Students are to plan and carry out experiments independently.

Students should document their test planning, implementation, variants, observations and results using appropriate technical language.

NoS:

Students are to become aware of the "scientificity" of their investigations.

Students are to pose and formulate scientific questions in everyday situations.

Station 6: Fridge

Students should learn about ventilation phenomenologically as a result of a temperature gradient.

Students should be able to describe and use the term "insulation" correctly.

Students should be able to explain the operation of the fridge professionally.

Students should be enabled to filter out the necessary information from the provided written materials.

Students are to develop test sets (fridges) independently on the basis of acquired knowledge.

Students should formulate manuals for the construction of experimental setups using appropriate technical language (including draft).

Station 7: Freezing Mixture

Students should be able to describe phenomenologically the freezing point depression (with the addition of salt, water is still liquid also at minus degrees).

Students are to conduct tests according to instructions independently.

Students are to review assumptions and confirm or disprove them.

Students should be able to filter out the necessary information from the provided written material.

Station 8: Snow, Fruits and Honey

Students should be able to describe that different substances have different freezing points (freezing point as material property).

Students should learn about the key stages in the history of ice cream.

Expansion of the technical terminology (thermal conductivity).

Students should be able to describe that different materials conduct heat differently.

Students are to conduct tests according to instructions independently.

Students should be able to apply their acquired knowledge to new problems.

Station 9: First Revolution in Ice Production: Freezing Mixtures

Students should learn about the history of the discovery and use of cold mixtures in scientific research and especially in the production of ice cream.

Students will create and produce a cooling mixture and make a simple ice cream.

Students should look for scientific contexts in everyday situations.

Station 10: Second Revolution in Ice Production: Refrigerating Machines

Students should understand the transition from traditional technology of ice cream production with the cold mixes to the ones with the new machines and compare the function and functional parts of the two techniques.

Students are to set out on the basis of their knowledge about the basic function of a mechanical electric ice cream maker in compliance with certain conditions at the beginning of the 19th century, and design their own ice cream machine and sketch their construction.

7. Students´ (Mis)Conceptions and Obstacles to Learning

Because this teaching unit is based on the ideas of thermodynamic structure as one of the important technical objectives, particular attention is to be paid here to the thermal conceptions of students.

Here, the misconception "wool is warming" (warming objects, such as sweaters, are associated with hot things) is one of the most important obstacles to be observed and to be overcome. This is concerning the parts of the teaching unit dealing with insulation.

Due to a serious misconception (such as: "metal is a better cold conductor", "Being cold or hot is a property of the material. Iron is cold, plastic is warm."), temperature sensation in the hands of equally hot objects made of different material should be explained explicitly with conceptions of energy conductors.

One difficulty may also occur with the idea of temperature constancy at phase transition points. This concerns station 4 in the treatment of the boiling temperature of water at low and high temperature of the environment.

Here special attention should be paid to the use of the term "heat". It is important to regard heat as a means of energy transportation, and thus to be treated as a process factor, and not to deepen the misconception (such as: heat is storable or the idea of heat as a material).

It is important to look at the differentiation of the terms heat and temperature because student tend to identify these two concepts.

8. Teaching and Learning Resources

8.1 Station 1: Life before the Fridge

Materials: worksheets with tasks

Station 1: Life before the Fridge

Task 1: In the table below you will learn some things about the history of cooling and ice cream - for example, new physical findings or technical devices.

Think about why people have dealt with that question and what they wanted to achieve. Some examples can be found already in the chart, complete the chart.

History of Cooling and Ice Cream Production	**For what purpose?** Your ideas:
Hippocrates (460-370 BC) taught his pupils of the medical school the special effect of ice cream on people: it invigorates the body and increases well-being.	*Example: to refresh and cheer up*
Alexander the Great (356-323 BC) had snow mixed with wine, milk, fruit juice or honey for refreshment during his conquest.	
Emperor Nero (37-68 AD) had runners, alternating between Rome and the nearby Alban hills. They should bring their pampered guests iced dessert made of snow, rose water, honey and fruit.	
Up to about 1850, natural ice was frequently used as a coolant. It was very expensive and not available throughout the year. Therefore people tried very early to produce ice themselves.	
Marco Polo (1254-1324) reported in Italy on his travels to Asia and China, where he had met previously unknown ice cream dishes.	

Approximately **1200**, Arabian doctors prescribed saltpetre for its cooling effect as a remedy for fever.	
In China, 600 BC, ice was already stored in special ice pits and ice cellars in the summer months.	*Example: produce ice cream and cool foods even in summer*
In 1688, Dalence (French scientist) used mixtures of salt and ice for his research on how temperature can be measured.	
In the **16th century**, Italian confectioners and pastry bakers described the cooling effect of saltpetre. That way they could also produce fatty liquids such as ice cream.	
Around 1850, the first machines were developed to produce artificial ice with which one could cool food e.g. These machines were called **chillers.**	

In 1799, the first shipload of ice from New York went to England. Afterwards the trade in ice from cold North America strongly increased.	

Until about 1950 wooden iceboxes were used to store the purchased ice for a longer period. They were also used to store ice in them that had been broken down from ponds in winter.	
In 1877, the German engineer **Carl von Linde** introduced his first refrigeration machine, which was able to cool air so strongly that it became liquid.	
From 1800 onwards, England's population rose very strongly (by advances in medicine and technology, fewer people died). Now there was barely enough food for all. From distant conquered areas food had to be brought by ship to England. They covered the food with ice blocks.	
F r e n c h p	

Example: producing better ice cream

Imagine the following:

You live with your tribe in a remote area. You live in cabins in the woods. You live of plants and also animals, which you have hunted. You do not always find enough food, so you should better create a stock.

Task 2: Write a short story about how you could store your food supply (e.g. meat, mushrooms, and berries).

It could start like this:

„Today I managed to slay a very big animal with my hunter comrades. This is how we store our food supply for a most possible long period…“

Alternative terms: ice, cave, dark, light, fur, stream, leaves, water, pit, shadow …

Info: In cold regions near the poles (very far north and south) cold is often seen as threatening stress. You have to protect yourselves against low temperatures and there are fewer edible plants.

In warmer regions near the equator cold was regarded a sought after luxury. Because of long periods of high temperatures many methods have been developed. So, one has learned in an intelligent observation of nature and wind, deep caves and arches, running water, to use mainly the cooling effect of evaporation.

Task 3:

a) In the info a few ideas for cooling have been mentioned, which people have copied from nature. How could you implement these ideas with the below mentioned materials?

   Write down how you would proceed to recreate the cooling methods. Make a drawing of your cooling device!

   Materials: thermometer, water cooker, tap water, ice, bulb, aluminum foil, paper, hair dryer, flower pots made of clay, fabric cloth...

b) In task 1, you thought about for what purpose people have engaged in cooling.
   Add your opinion and justify: Does research in science always have a certain purpose?

8.2. Station 2: Cooling by Evaporation

Materials:
• worksheets with tasks
• **Materials for Task 2** (determination of wind direction) depend on the suggestions of the pupils (e.g. cup of water, fans / blower "to make wind")
• **Materials for Task 3** (factors affecting evaporation)
- ventilator
- stopwatch
- thermometer
- mouthwash
- water
- juice
- detergent
- Bunsen burner
- cup vessels with different diameters
- measuring cups

Station 2: Cooling by Evaporation

Info:

By cleverly observing nature, people learned above all to use the cooling effect of evaporation (liquid water turns into steam) next to air draught, deep caves and vaults or running water. For example, they wrapped wet towels around filled clay pots and exposed them to the wind. This is known to us from old texts as well as from Egyptian grave drawings. In Egypt, India and other hot countries, there was generally a big problem with cooling foods and drinks. Therefore by and by, time-consuming processes for the production or procurement of cooling agents (cold water / ice) developed. Thus, in the Indus area and the Nile plain, hallow clay pots were filled with water and set on thick straw material in 45 cm deep earth pits. Or the vessels were placed on the flat roofs of the houses. That way in cool nights a lowering of the water temperature could be reached below freezing. The night air was extremely dry and therefore was able to absorb a lot of evaporating water. The night wind increased this effect, taking away the damp air.

The Englishwoman, Fanny Parks, whose husband supervised the ice harvest (collecting ice for stock) in a facility in India in 1828, reported that by using this method up to 12,000 kg of ice could be produced in the period from the 22nd January to 19th February. Several hundred men, women and children were busy filling the bowls. When the water was frozen (approximately by 3 o'clock in the morning) the workers came back, hit out the ice and carried it to the pits in baskets. Until April these pits were solidly sealed. It was not until then, and until August the ice was sold.

As early as 500 BC the Greek philosopher Pythagoras reports on this method of ice extraction in Egypt. Also in Central America they used earthenware bowls for ice production.

Task 1:

a) Read the text.

b) Put some drops of water on your hands. Now rub the water between your hands, and hold them closely in front of you with your palms up.

Describe your observations and try to explain them. What does it have to do with how they used to cool in former times?

Task 2:

You know now that the objects on which water evaporates become cooler. How can you determine the wind direction in a simple way, using this knowledge? Plan your approach and execute it. Write down exactly what you observe and how you can explain this observation with your knowledge.

Task 3:

Imagine you are a scientist and you do research in the field of cooling. Now you examine cooling by evaporation closer.

You know already that water cools down when evaporating and that the wind plays a role in it. But what about other liquids?
Now you suspect that various liquids cool at different rates.

In addition, you can imagine that on large surfaces more water evaporates in the same time than on small ones. Now you suspect that liquids in containers with a small opening cool more slowly than with a large opening.

Make a test now, so you can answer the following research questions:

1) How quickly do various fluids cool down?
   What cools the fastest?
2) How does the surface above which the fluid can evaporate in a vessel have an effect on the speed with which the liquid cools in it?

Equipment: fan, stop watch, detergent, a thermometer, mouthwash, water, juice, Bunsen burner, beakers, vessels with different diameters, measuring cups.

Plan the test
To 1): Make sure that ONLY the liquid changes (not the cup, the amount of fluid, etc.) All liquids must have the same temperature at start!

To 2): Make sure that ONLY the surface changes (not the cup, the amount of fluid, the fluid itself, etc.). The liquid must have the same temperature before each experiment!

Answer very briefly:
Why would scientists pay attention to such things?

Perform the test
Make sketches of your experiments and write down your thoughts.
Place assumptions on what will happen.
Write down your observations.
Write down whether your observations speak for or against your expectations.
Give answers to the research questions 1) and 2) and make very clear what observations and which assumption you used for it.

8.3. Station 3: „Pot-in-Pot"- Fridge

Materials:

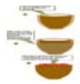
- • worksheets with tasks

Materials for task 1 (Factors in the pot-in-pot cooling):

- thermometer
- sand
- flower pots of different sizes
- flaps
- hair dryer / fan
- ice
- water
- ...

- **Station 3: „Pot-in-Pot“ Fridge**

<u>Info:</u> The north of Nigeria is a poor and very hot region where people live of tedious farming. Without electricity - thus without refrigerators - much food spoils within days. The farmers living from selling these foods, earn only very little money and often suffer from diseases caused by the consumption of tainted foods. Even in cities many people cannot afford a refrigerator.
Motivated by concern for the rural population and led by the thought of a simple but functional technical implementation the Nigerian teacher Mohammed Bah Abba was looking for a solution to this problem.



Bah Abba was born into a family of potters and learned very early the art of pottery. He knew that finished clay pots are firm enough for storage of food even when still moist. Later he combined this experience with the knowledge he had acquired in the study of biology, chemistry and geology:

A clay pot is placed in a slightly larger clay pot. The space between the two is filled with wet sand, the food to be cooled is placed in the inner pot and covered with a damp cloth.

The water from the sand slowly penetrates into the outer container and evaporates on its outer surface. In the hot African climate, the water evaporates very quickly. Due to the evaporation the water cools and thus the sand and the inner pot. The goods stored in it remain cool and fresh this way. If the sand dried, some water must be refilled, so the "fridge" continues to work.

The shelf life of food is extended considerably by the pot-in-pot method, and particularly if the pot is positioned at a windy location. Eggplants stay fresh up to 27 days instead of only three days. Paprika keeps over three weeks longer than non-chilled and African spinach, which usually spoils after one day, is still edible after 12 days. The farmers benefited from this invention. Since their products were no longer threatened to spoil as quickly, they were not forced to sell quickly at any price. They were able to increase their revenues significantly.

Things turn cool when there is evaporation on the surface of water. Actually, everybody who has ever licked his finger and held it into the wind to determine the direction from where it comes knows the effect of evaporative cooling.

Task 1:
In the text you learned a bit about the history of the development of the “pot-in-pot refrigerator”.

1) Why did Bah Abba deal with the development of the "pot-in-pot refrigerator"?
2) What knowledge did Bah Abba use to develop the "refrigerator"?

Task 2:
You know that water cools with evaporation and that wind also plays a role. But how is the "pot-in-pot refrigerator" affected by the moisture of the sand?

Plan a test, so you can answer the following research question:

How does the amount of water in the sand, affect the temperature in the inner pot?

Equipment: scales, measuring cups, thermometers, sand, flower pots of different sizes, cloth, fans, ice,...

- Place a guess on the research question.
- Think carefully about experiments with which you can test your assumption.
- Make sketches of your experiments and write down your previous considerations.
- Perform the experiments, note down your observations.
- Check if your observations speak for or against your hypothesis.
- Answer the research questions and make very clear,
- what observations and what assumption you've used for it.

Task 3:

a) Write down: What is science for you rather – what Bah Abba did or what you did in task 2? Explain your answer.

b) Consider with the example of Bah Abba: how do scientists choose, what questions they should work on?
Discuss your ideas in the group!

Task 4:
This is a "mini clay fridge" by an Indian manufacturer.
On top it has a filling funnel and at the bottom a drain for water.

Write down:
How could this mini clay fridge work in a rather hot country like India?

opening with lid

compartments for food

drainage

8.4. Station 4: Modern Refrigerator

Materials:

- • worksheets with tasks
- **Materials for task 2** (boiling water, normal):

- hot plate
- 250 ml water
- thermometer (range up to 100 ° C.)
- stands (bar, foot, a sleeve, a stand clamp)
- beaker (approx. 500 ml)

- **Materials for Task 3** (water boiling, version in the oven):

  - about 250 ml of preheated water
  - oven
  - pot for the stove or glass beaker from thermal glass
  - oven thermometer

Station 4: Modern Refrigerator

kitchen/room **refrigerator**

Task 1: Between1800-1900, many scientists researched new methods to produce cooling effects without the use of natural ice. They also tried to improve known methods. In the table you find possible reasons why the researchers have pursued development of artificial cooling.

Mark five things, which in your opinion have especially influenced research.

Natural ice was very expensive and not available throughout the year.	
Up to about 1850 cooling with natural ice was the only device.	
Carl Linde, a mechanical engineering professor from Munich, who built the first German cooling machine in 1876, wanted to be famous.	
Around 1400, sugar was so expensive that it was sold in pharmacies as a medicine in gram portions. From 1825 it was possible to get cheaper sugar from sugar beets. Now many people could actually buy ice cream - if not so much natural ice would be necessary for the preparation.	
One just wanted to outwit nature, and produce ice artificially.	
The wife of Carl Linde wanted a new refrigerator.	
The brewers were in search of new cooling techniques. Rock caverns and natural ice were no longer sufficient for the growing beer production.	
Using the cooling technology they wanted to ship foods from distant countries, without spoiling it during the long journey.	
Ice cream was a luxury item. But the poor among the population wanted to eat ice cream and envied rich people.	
In Australia, New Zealand and South America there was great interest in selling the surplus of cattle and sheep to England. The transport required enormous quantities of ice, for 1 kg of meat needed 8 kg of ice.	
America had exceptionally lots of natural ice due to its large cold regions.	
Natural ice was - compared to the artificially produced - often dirty and therefore not suitable for human consumption.	

Some physicists have permanently worked in their experiments at low and very low temperatures.	
In 1880, Lord Kelvin constructed a refrigerated meat transport vessel from Sydney to London. He developed a cooling engine in which a kind of alcohol was used as coolant. However, such first refrigeration machines often caused serious accidents if the coolant leaked and exploded. Therefore one looked for safer solutions for refrigerators.	

With ice-salt mixtures one could indeed produce low temperatures. However, scientists found it not interesting to experiment with them any longer.	
Scientists have gathered enough knowledge to develop refrigeration machines.	
In Europe and America skating halls should be built. Especially smooth frozen surfaces were needed, without air inclusions.	
In order for Professor Carl Linde to give his students practical instruction as well, the Bavarian government sponsored 70 000 guilders for the establishment of a machine laboratory. There he could continue his research on new cooling methods.	
There has been lots of trading with natural ice. Therefore natural ice merchants earned much money. Some people did not grant the sellers of natural ice their wealth and would have liked to see them go bankrupt.	

Consider now more generally, what is affecting researchers to conduct research.
Write down your ideas.

Task 2: You certainly have made water boil or at least watched it. You know already that the water is very hot. But have you also really watched more closely, how temperature changes when the water is boiling? This is what you are to catch up in this experiment.

Materials: immersion heater, large glass beaker, water, thermometer (range up to 150 ° C), stand equipment (pole, base, a sleeve, a stand clamp), stopwatch

You go about as follows:

- Pour the water into the glass beaker.
- Put the immersion heater into the glass beaker.
- Build up the tripod and mount the thermometer on the tripod clip so that it dives into the water, but does not touch the immersion heater.
- Turn on the immersion heater.
- **Remember that boiling water is very hot. Let all equipment cool off before you clean up, so you do not burn yourself!**

1) How does the temperature change, **until** the water boils?
2) How does the temperature change, **while** the water is boiling? (Watch it at least for 2 minutes!)

Write down your observations in bullet points and note at equal intervals the temperature readings in a table.
Answer questions 1) and 2).
Why is it important that the thermometer does not touch the ground?

Task 3: In the last task you have already boiled water. But there are other ways to bring water to a boil, as you will see in the next attempt:

Materials: ca. 250 ml preheated water, oven, pot for the oven, oven thermometer, stopwatch

You go about as follows:

- Pour 250 ml of the heated water into the pot.

- Place the oven thermometer in the pot.
- Put the pot into the oven and choose a temperature of 200 ° C.

1) How does the temperature change, **until** the water boils?
2) How does the temperature change, **while** the water is boiling? (Watch it at least for 2 minutes!)

Write down your observations in bullet points and note at equal intervals the temperature readings in a table.
Answer questions 1) and 2).

Speculate: Why does the temperature of the water behave like this while it is cooking?

Task 4:
What temperatures prevail around the boiling water in task 2 and task 3? Compare these outer temperatures with the temperature of boiling water. Write down your results.

Task 5:
Imagine now a being who is accustomed to temperatures of 200 ° C and it feels well with it. The oven with a temperature of 200 ° C would be the optimal biosphere for this creature.

How exactly would the boiling water in the oven feel for this being?

If you are uncertain, it may help if you have a look in your records, which temperature boiling water had.

We also know this feeling when we work with liquid nitrogen, for example (see picture).

For us humans about 25 ° C are pleasant. Liquid nitrogen “boils" at –196 ° C. If you were in the kitchen pouring liquid nitrogen into a bowl, its temperature would be –196 ° C!

It is interesting that a substance is boiling and yet it's so cold! Instead of using the term "cooking", you should use the physical term "boiling".

Boiling at low temperatures was known already early.
The knowledge of this effect was the basis for the development of the first refrigeration machine. The effect is still currently used in refrigerators.

<u>Info:</u> In 1877, the German engineer Carl von Linde introduced his first refrigeration machine. Even today, refrigerators function like Linde´s refrigeration machine.
A refrigerator works by constantly repeating certain processes:

Kühlmittel im Rohr

- *In (1) there is a coolant in the pipe that is much warmer than the air. It gives its heat to the surrounding. This happens at the warm back side of the refrigerator.*
- *The coolant flows through the pipe (2) in the interior of the refrigerator, where it is brought to a boil (it boils at a low temperature just like nitrogen). Coolant evaporates and thus cools off the inside of the fridge - the coolant in the pipe (3) takes up the heat of from the interior of the refrigerator while evaporating.*
- *The coolant is then pumped out as gas through the pipe of the fridge. At (4) it is compressed. It is liquid again and hot.*

  Now it can start all over again.

<u>So, very briefly:</u>

This is called „Linde-method".

Linde succeeded also to liquefy air at -189°C.

Below this temperature, the air is liquid, above it is a gas. This point is called "boiling point" of the air. Air is actually already boiling at very low temperatures, and yet we do not burn ourselves, but we would get frostbite even if we came in contact with air at the boiling point.

Each substance has a specific boiling point - which is one of the typical properties of substances (as well as the melting point).

<u>Task 6</u>: Thomas and his sister Sarah are both in front of the refrigerator and argue. Thomas insists that: "The refrigerator transports cold into the refrigerator. Otherwise it would not be so cold in there!" His sister Sarah on the other hand replies,"Where should the cold come from? I think it's the heat that is removed."
You've already learned a lot about the working of a refrigerator. Who of the two fighting cocks would you agree with? Explain your answer by referring to your knowledge of the operation of refrigerators!

<u>Info</u>: The first refrigeration equipment was not safe: When ammonia was used as coolant, it caused severe poisoning when it leaks from the refrigerator. Other coolants were also very dangerous because they could easily explode. They too, caused serious accidents.

Chemists went on to develop new and safe means for cooling, e.g. CFCs, which has been used as a coolant in refrigerators for a long time. It turned out later, however, that CFCs are harmful to the environment: The agent breaks down the protective ozone layer in the upper atmosphere.
Chemists kept on investigating new safe and environmentally friendly resources that are now used extensively in modern refrigerators.
But there are also some exceptions which is shown by this newspaper article:

Leaking ammonia makes apartment temporarily uninhabitable

Saarbrücken. On 17.03.2009 at 18:00 clock a bad smell in an apartment in Red Mountain Road was reported to the police in St. John.

The resident informed the police after he noticed a pungent smell.
Since the arriving police officers could not determine the cause of the foul stench,
they suspected a faulty gas line. So the fire department was notified.
They found that the cause was an old broken fridge in the apartment.
Toxic ammonia leaked out of it. Only by luck no persons were injured.

Task 7:

Think about it and write down:
Are scientists responsible, if they achieve new knowledge that could do harm to humans or the environment? Find other examples and a reason for your answer.

8.5. Station 5: Ice House

Materials:

• worksheets with tasks
• Materials for Task 1 (investigation of the best insulation of ice):
- thermometer
- ice cubes
- light bulbs (heat lamps)
- stopwatch
- cake roll
- aluminum foil
- towel (or scarf)
- wet rag
- a dry cloth
- wood chips ....

Station 5: Ice House

<u>Info:</u> In winter when the lakes were frozen, they were ice "harvested". This natural ice and also snow was used for cooling food since a very long time. In China they stored the resulting natural ice and glacial snow in special deep and cold caves and ice cellars for thousands of years. Until about 1930, there were also many ice cellars and ice houses in America and Europe, where the ice had to be kept as long as possible. Particularly in the free-standing icehouses it was very difficult to save the ice from melting.

A material that conducts heat very poorly is called an "insulator."
They were searching for materials that insulated well in those days.

<u>Task1:</u> You've probably already made the experience that you have bought an ice cream on a warm day and you could not eat it as fast as it melted.
You shall now try and solve the problem to keep an ice cube without a fridge as long as possible.

- Plan to implement an experiment with the materials available.
  After the test you should be able to answer the following research question:
  Which material keeps an ice cube from melting for the longest time?

<u>Materials:</u> thermometer, ice cubes, light bulbs (or infrared emitters), stopwatch, kitchen roll, aluminum foil, towel (or scarf), wet cloth, dry cloth, wood chips, container ...

- Make a sketch of your design.
- Run your experiment and note down your observations.
  (In case you must wait, begin with task 2 already)
- Please answer the research question.

<u>Task 2:</u>
You might have to wait a little until your investigation is complete.
It is very important in science to record exactly how one has approached ones research. This is the only way that other scientist can understand and solve the problem and possibly point out errors.

Write a short text, about how you approached the investigation. Here you can use, for example, the following words (but you don´t have to): *problem, question, prior knowledge, observe, presumption, plan, try out, review test, measure, outcome, ..*

<u>Task 3:</u> New scientific findings must be published so that people can use this in their decisions and to help other scientists who want to continue working with it. Frequently, researchers summarize their results in a scientific article.
That knowledge is then used also to improve technical equipment.

In task 1 you have gained knowledge of good and less good insulators.

1) Write now, based on your new findings a brief introduction to the book "The Ice House" (see picture above).

Then explain, for example with a plan on how to build a good ice house.
Describe the process of the information that you use and how you thought about it.

2) Why should you indicate where you have the knowledge from which you want to use?

3) Do you agree with the following sentence? Give reasons for your answer!

"Science is producing new knowledge
and in technology this knowledge is used."

Task 4:

The film strip shows how natural ice was once obtained from lakes and rivers.
Use the space left of the filmstrip and write down a question that you think, scientists would also like to pursue in their research.
Explain then, why scientists would ask this question?
(Scientists conduct research not only because it is so interesting!)

Every year, when the ice thickness had reached its maximum 18 to 20 cm ... Question: ______________________________ ______________________________ ______________________________ REASON: ______________________________ ______________________________ ______________________________
... large sheets of ice were cut from the ice with picks and saws... Question: ______________________________ ______________________________ ______________________________ REASON: ______________________________ ______________________________ ______________________________
... and drawn with pitons on previously leveled snow paths to the shore. There, the plates were broken into portable pieces of about 20-25 kg and loaded onto horse-drawn carriages ... Question: ______________________________ ______________________________ ______________________________ REASON: ______________________________ ______________________________ ______________________________
... and transported to the ice houses. Question: ______________________________ ______________________________ ______________________________ REASON: ______________________________ ______________________________

Having arrived at the earth or ice house, the ice blocks were unloaded and deposited into the existing ice house. Question: ____________________ ____________________ ____________________ REASON: ____________________ ____________________
The ice was okay for cooling, though it was not particularly clean. Question: ____________________ ____________________ ____________________ REASON: ____________________ ____________________ ____________________

8.6. Station 6: Fridge

Materials:

• worksheets with tasks

• Materials for Task 2 (construction of a refrigerator)

- box
- scissors
- scotch tape
- adhesive
- kitchen roll
- cling foil
- aluminum foil
- wood chips
- cotton pads

- Station 6: Fridge

<u>Info:</u> Until about 1950, wooden or iron fridges were used. A fridge is the forerunner of the refrigerator as a household unit for cooling and keeping food fresh.

*That was a long-legged cabinet, were food was kept in. Crushed ice was put into a compartment at the top. Below the dripping water was collected. The ice was placed **above the food storage compartments** in order to make the rising warmer air sink again (warm air rises and cool air sinks). To grant that the air in the cabinet could move well, food was placed on wire grids.*
*The **insulation** (material that conducts heat very poorly) consisted of layers of sawdust and straw in the walls of the cabinet.*
Because the melting ice had constantly to be renewed (almost every day in the summer), this form of cooling was associated with a lot of work: the meltwater had to be poured off and the fridge had to be cleaned once a week; also one had to regularly re-order ice.
The ice blocks were delivered to the house by icemen who transported the heavy blocks by horse carts. Besides the natural ice (from frozen rivers and lakes) soon artificially produced ice was sold. This so-called "crystallized ice" was especially popular because of its cleanliness, but was also much more expensive than natural ice.

*Despite such disadvantages of the fridges, they were only **very slowly** replaced by the first **refrigerators**, which were very large and expensive.*

<u>Task 1:</u>
Read or listen to the text. Look at the pictures of the fridge. Fill out the table below:

Place a guess on: Why the fridge should have relatively long legs?	
Give reasons: - What is the dish under the fridge for? - Why was the ice put in the upper and not in the lower part of the closet?	
Explain why food in the fridge was not simply placed on thick metal tins, but on wire grids?	

The interior of the cabinet was separated from the surrounding area with a thick insulating layer (layer of materials that hardly let through heat). Explain why.	
Describe why this form of cooling was associated with a lot of work.	

Task 2: Create a small model of a fridge from materials available. Make a drawing before you start and justify why your fridge can keep food cold!

Materials available: cardboard, scissors, scotch tape, glue, paper towels, cling foil, aluminum foil, wood chips, cotton, ...

8.7. Station 7: Freezing Mixture

- **materials:**

worksheets with tasks

materials for task 1 (for freezing point depression):
thermometer
2 glasses
ice cubes
salt

materials for task 2 (optimization of salt-water mixture):
thermometer
glasses / cups
crushed ice
water
salt

Station 7: Freezing Mixture

A scientific study on salt and ice

Info:

You may have noticed that in the winter salt is scattered on the streets to clear them of snow and ice. Afterwards, the road is wet, ice and snow are melted.

One can ask now:
Question: But why does ice melt when it is mixed with salt?

What do we know already?
You know already that ice melts when it is warmer than 0 degrees Celsius.
(This temperature is called the **melting point** of ice).

Using this knowledge you could already set up an assumption:
Assumption: ice mixed with salt is warmer than 0 degrees Celsius.
(Consequently the street turns warm.)

Consider whether you already had observations that speak for or against this assumption.
Discuss it with your classmates and find out their opinion.
Write down what would speak for and what against the "warm-road assumption”.

If you reconsider the assumption you might perhaps find the answer to the question.
If it is so, you can answer the question.
If it is not correct, then the ice melts for a different reason. But at least you know now that it is not because it is getting warmer.

Execute the following investigation.

Investigation 1

Because we do not want to wait for snow and winter,
we recreate the road situation.

Materials: thermometer, 2 small glasses/cups, ice cubes (same size), salt

Test before:

(1) Does the ice-melting with salt also work in the classroom (instead of on the road)?
Take two ice cubes and put each in a small glass.
On one of the dices scatter 2 tablespoons of salt.

a) What do you expect? Why are you expecting this?
b) What do you observe?
c) What do you conclude?

Test the assumption:

(2) Ice mixed with salt is warmer than 0 degrees Celsius.
Measure now as close as possible to the ice cubes both the temperatures of the ice melt water.

a) What do you expect? Why are you expecting this?
b) What do you observe?
c) What do you conclude to believe? Why do you conclude it?
(Name the observations that speak for or against the conjecture.)
d) How would you now answer the research question "Why does ice melt when mixed with salt?”
(Look again to the previous page)

Task:

Think and write down:
Sometimes scientists get results which disprove their hypothesis.
Is that good or bad? Give reasons for your opinion!

Info: The need for cooling has been a very long time, and far widespread. This is shown by many reports, for example

from China, where 2600 years ago, ice was kept for the summer months.

from India: where they put water in shallow bowls in pits or on rooftops during cool nights. Before sunrise, a layer of ice formed on the water.

....

Previously one did not have refrigeration machines available (see station 4). If one wanted to produce low temperatures one had to use a special technique for it.

This was made as follows:
They mixed water or ice with salt. In particular they took advantage of certain salts, which leaked from damp basement walls. This "saltpetre" (the salt scraped from the stone basement walls) was a part of the manure, which came from the adjacent drain or manure pile through the cellar wall.
They had observed that salt had a strong cooling effect: for example, if one mixed saltpetre with snow, the temperature of the mixture greatly decreased.

Today these mixtures of ice with salt are known as freezing mixtures.

Investigation 2:

400 years ago, ice, but most of all salt was difficult procure in many areas and therefore very expensive. If one produced cold mixes there, one did not want to waste any of it, and yet still cool with it as much as possible.
So when you're producing a freezing mixture with ice in a container, one wants to know how the amount of this mixed salt affects the temperature of the mixture.

Try and imagine you're a person of that time and you want to solve this problem, because you are not very rich. Carry out an investigation with which you can answer the following research question:

Which mixture of salt and ice produces the freezing mixture with the lowest temperature so that it is not worthwhile adding more salt?

Devices: crushed ice, salt, scale, tablespoon, cups, thermometer (a thermometer as we know it today, people at that time actually did not have!).

This is how you can prepare a good freezing mixture: alternately put a thick layer of ice and a thin layer of salt in one cup. If your layering is ready, stir the mixture well. Now you can measure the internal temperature of your freezing mixture.

Prepare three or more freezing mixtures. Shuffle for the same amount of ice with different amounts of salt

- 200 grams of ice and 40 grams of salt; mixture 1
- 200 grams of ice and 60 grams of salt; mixture 2
- 200 grams of ice and 80 grams of salt; mixture 3
- etc.

Note the lowest temperature each mixture reaches. Then write down the temperature and the data of the freezing mixture (ice volume, amount of salt), in the following table.

Various salt/ice mixtures:

Amount of salt in gram:

Amount of ice in gram:

Lowest temperature in °C:

Can you answer your research question now? Use your data to reach a conclusion.

Task for investigation 2:

Now imagine again you lived 400 years ago, and you have carried out your investigation. You have just read the following in a newspaper:

Research with freezing mixtures should be allowed only to wealthy scientists, since only they can afford the necessary salt. As everyone knows, freezing mixtures are getting colder, the more salt one is adding to it. Investigations at lowest temperatures will remain impossible for most scientists. You should focus on other areas.

State your position by writing a letter to the author of the article. Present your investitgation and your results in a way that he is convinced of your results.

The letter could start like this:
"Dear author of the article on freezing mixtures. You wrote that freezing mixtures may be getting ever colder, if only you added more salt. Just recently I conducted a study to the effect that ..."

8.8. Station 8: Snow, Fruits and Honey

Materials:

- worksheets with tasks
- **Material for task 1** (order of stories on ice cream)
  - scissors
  - glue
- **Materials for task 2** (thermal conductivity of different materials)
  - a glass of tea or cup
  - three long spoons, from metal, wood, and plastic
  - tea bags
  - hot water.

Station 8: Snow, Fruits and Honey

Task 1:

Ice cream has been around a long time. The **first ice cream** was very different from our ice cream, because milk or cream could not be frozen then. Water freezes at 0 ° C. Milk and cream contain fat and thus it must be much colder for it to freeze.

You have individual stories about ice cream on different cards.

Read all cards

Cut them out and

glue them in the correct chronological order on the prefabricated sheet.

- The Venetian merchant and explorer **Marco Polo** (1254-1324) reported in 1300 on ice desserts in China, Central Asia and the Orient. He said that over 3000 years ago the Chinese knew ice cream already. He brought a recipe for making ice cream as a gift of Mongol prince Kublai Khan. That is how in 1300, the knowledge about ice cream came back to Europe.
- In 1040 AD, the **Sultan of Cairo** built a whole transport chain of refrigerated goods, to make his life more bearable. Every day, 14 camel-loads of snow came from Syria to his palace.
- After the fall of the **Roman Empire** (ca. 500 AD) the knowledge about ice cream making was lost in Europe.

Emperor Nero (37-68 AD) established a runner's chain between Rome and the nearby Alban Hills to be able to offer iced dessert made of snow, rose water, honey and fruit to his pampered guests. Nero allegedly ordered to kill those runners who could not manage to bring him the snow before it melted.

As early as 3000 BC ice cream was produced in **China**. They kept ice and snow in ice cellars and made ice cream out of it in the summer. The recipes were very simple: ice cream mixed with milk or fruit juices, spices and honey.

The famous physician **Hippocrates** (460-375 BC), already knew that ice and snow stimulates the body fluids and highlights well-being. He prescribed ice as medicine and painkiller.

Before Alexander the Great went (356-323 BC) into war, he handed out apple juice, mixed with honey and snow to his soldiers. By accident, he had found conserved snow in pits in the mountains. Ever since he used this method in order to always have cold drinks and ice cream.

Task 2: What will warm more quickly?

Material:
- a glass or cup of tea;
- spoon (silver / stainless steel / wood / plastic / glass)
- tea bags, hot water (kettle).

Procedure: Prepare a cup of tea by first giving the tea bag into the cup and filling it with hot water. Place now all the spoons into the jar, let the tea brew for 2 minutes.

Each spoon **conducts heat** from its lower end to the top **at different rates**.

What do you think, which of the spoons is heated up most in 2 minutes and which were less warm?

Now touch all the spoons successively at the top.

Describe your observations. Make an attempt to explain your observations.

Task 3:

In task 1 you have read how the runners of Emperor Nero had to make efforts and try to get to the palace before the snow melted. Maybe you can help them with your knowledge you acquired from task 2.

As a young scientist you've tried this out in task 2 already and examined different materials to find out whether they conduct heat well or bad. Use your knowledge to help Nero's runners to escape death penalty. What would you suggest them?

Task 4:

In task 1 you have read that the technique of ice cream production was lost and was re-introduced only much later.
Write down your ideas and give reasons:
How is that in the natural sciences? Can scientific knowledge change?

8.9. Station 9: First Revolution in Ice Production: Freezing Mixtures

Materials:

- worksheets with tasks
- **Materials for task 3** (producing ice)
    - small saucepan
    - plastic bucket /-bowl or (larger than the pan)
    - wooden spoon or spatula

Station 9: First Revolution in Ice Production: Freezing Mixtures

Info1: *The first ice was pretty far away from our ice cream, for a long time you could not freeze milk or cream. Water freezes at 0 ° C. Milk and cream contain fat and in order for it to freeze at all, it must be much colder. Cream e.g. congeals at -20 ° C.*

Task 1: Already In the 16th century, Italian confectioners have discovered that such low temperatures can be achieved using so-called cold mixtures: ice mixed with salt gets very cold (down to minus 21 degrees Celsius).
That is what the man in the picture cools his ice cream with.

Mark the container with the cold mixture and the container with the ice cream in the picture.

container with

container with

Info 2:

- *In 1530, a curious confectioner from Catania (Sicily) observed that saltpetre (a type of salt) lowers the temperature of the water to cool his wine so strongly that it begins to freeze. He scraped off the crust, a new one formed, and so gradually frozen water emerged – that was snow-like ice. For a long time no one recognized the importance of this invention. It was even used as a magic trick at fun fairs.*
- *In1550, the Spanish doctor Blasius Villafranca prescribes the application of artificial refrigerants (water-salt mixture) for lowering fever.*
- *In 1626, a certain Santorio achieved the lowest temperature of a cold mixture by mixing salt and ice in a ratio of 1 to 3.*
- *In 1635, the Italian physicist Aggiunti carries out academic studies with various freezing mixtures. He studied the effect of different types of salt.*
- *In 1724, the German physicist Fahrenheit used the lowest possible temperature with salt and ice to set the zero point of his thermometer.*
- *The Italian doctor Monardus claimed that cooling with saltpetre was invented and spread by thirsty galley slaves (slaves on a rowing boat).*
- *There are reports that the use of salt for cooling was known in China and Asia much earlier than in Europe.*

Task 2: Read info 2. This is the story of freezing mixtures.

a) Describe what came first - the use of freezing mixtures in everyday life or the scientific investigation of freezing mixtures?

b) Think about it and write down your ideas: How does everyday knowledge become scientific knowledge? What do you think, may it also be reversed: scientific knowledge becomes everyday knowledge? If so, give reasons for your opinion?

Info 3: Here is an excerpt from the old recipe in the "Economic Guide for Dames" (1803):

To half amount of good milk you add the desired ingredients with a little bit of sugar, and put it in an iron box, and set the same into a high bucket. Crushed ice should be placed all around, which must constantly *be turned. If the frozen amount now sticks to the iron box, the frozen bits are taken off diligently with a long wooden spoon and mixed with the not yet frozen. A little bit of salt will be added to the ice in the bucket to make it freeze more. If the ice in the can is now quite frozen, it is filled with spoons into cups...*

Task 3: Read the recipe.

a) Make your own ice cream. Keep to the instructions in the recipe.
Your freezing mixture: ice-salt mixture (about three times as much ice as salt);
Your ingredients for the ice cream: cream, sugar, spices, fruits, nuts, ...

Materials:
Small cooking pot, plastic bucket / bowl (larger than the pot), cooking spoons

While one of your group members is stirring your ice cream, try to explain:

- Why should the inner box be of iron?
- Why should you scrape the solid ice cream from the tin walls time and again?

b) Think of other questions about ice production, which you think can be answered scientifically, and write them down.

8.10. Station 10: Second Revolution in Ice Production: Refrigerating Machines

Materials:

- worksheets with tasks

Station 10: Second Revolution in Ice Production: Electric Refrigerating Machines

Info 1: *from a book „The elegant tea table" (1816):*

The ice is broken up into small pieces, put in a container and salted. Then the tin is filled with the amount of ice. The iron tin is now turned around fast at the grip for about one quarter hour. During this time the ice begins to develop something like a skin. Then the box is taken out, with a freeze spatula the ice is scraped from the walls, well mixed and stirred with continued turning, kicking and grinding ...

Task 1: To understand the described operation of one of the first ice cream makers, try the following experiment: take an empty plastic bottle, fill the bottle with water to a quarter. Move the bottle, so that a vortex is created:

- Write down your observation.
- Try to explain, why one should turn the tin with the still liquid ice cream mass very fast in the container with a salt-ice mixture.

Attention! If you still do not know what this mixture is, ask your classmates at stations 7 and 9!

Info 2: *America – First Patented Ice Cream Maker*

The first mechanical ice machine was invented in **1843** by the American housewife **Nancy Johnson** and patented. It was a hand-operated ice cream maker. The inner can was placed into a larger outer bucket, between the walls salt and snow was scattered. The mixture gets very cold, and a thin layer of milk freezes on the wall of the inner pot. A rotating paddle wheel scratches off this layer, so that a new layer of frozen milk can form.

Task 2: Fill in the box next to the image with the following words: inner pot, outer bucket, salt with snow, paddle wheel.

Info 3:

Here are two old German ice cream makers. They both work similarly to the first American ice cream maker by Ms. Johnson.
The ice machine on the left was powered by hand - you can see a handle on the wheel. The one on the right is running with an electric motor. This has saved a lot of work, and allowed to prepare more ice cream and faster.

Task 3: *Imagine you're living in the year 1905. Design your own ice cream maker. Please remember:*

- Ice procurement for freezing mixtures (ice and salt) was relatively expensive.
- In those days, salt was not very expensive.
- Electric motors replaced the manual agitator and were more effective.
- Belts (special belt - see picture), which ran from the engines to the agitator could often cause injuries and were therefore dangerous.

Decide on a mechanical or an electrical ice machine, after you consider the top arguments against each other. Write down your thoughts.
Note down, which machine you have chosen? Why?

Make a sketch of your ice machine and explain how it works.

Info 4: *What happens to ice when it will sit longer? How would its temperature behave? At the beginning of the 20th century, it was very important for industry and economy to keep things very cold, and at the same temperature. This is exactly why the search for new cooling options continued. In 1876, German professor Carl Linde invents a refrigerator that needs neither natural ice nor salt. It creates artificial cold and can replace freezing mixtures by and by. With this progress in refrigeration technology, finally ice cream is made available for all.*

Task 4: Below left you see a modern ice cream maker. It has similarities with the old ice machines (below right). It does not cool any longer with a salt-ice mixture, but works like a refrigerator (Station 4). It has an electric drive. Just like in the refrigerators heat is withdrawn from the ice by a particular refrigerant (e.g. ammonia). In the ice machine is a double-walled tank. Between its walls is the refrigerant and in the interior the mix of ingredients for the ice. The refrigerant is evaporated again and again, and extracts heat from the inner cylinder. The freezing ice on the cylinder wall is scraped off with the help of a stirring device and scraper.

agitator

refrigerant

drive

- Read the text.
- Use your knowledge about old and new ice machines from the previous texts, and compare (what remained the same or stayed similar, and what has changed).

Graphic material for 5.2.1. Cooling Technology

8.11. Graphic material

Bildmaterial zu 5.2.1. Kältetechnik

Abb. 1

Abb. 2

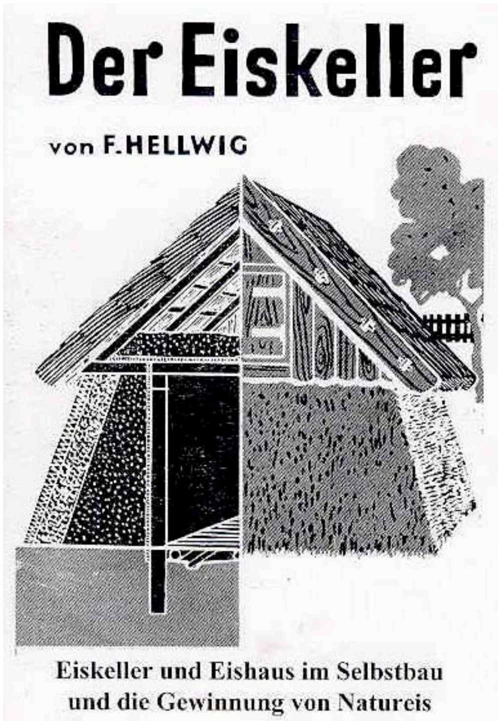


Abb. 3

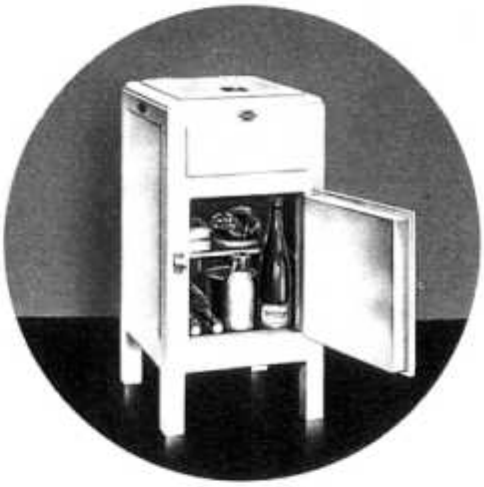
Abb. 4

ORIGINAL VEWAG ESCHEBACH

ESCHEBACH-EISSCHRÄNKE

Besonders preiswerte Modelle

Nr. 881/5 Ziso · Nr. 881/5 E



Eiskasten mit Doppelrost, herausnehmbar, aus Stahlblech, im Vollbade verzinkt, Beschläge vernickelt, Rostauflage mit 2 halben Holzrosten. Auf Wunsch mit Schmelzwasserkasten.

Außen weiße Öllackierung.

Nr. 881/5 Ziso = Auskleidung Zinkblech.

Nr. 881/5 E — Auskleidung Stahlblech, weiß emailliert.

Nr.	Außenmaße			Nutzraum	Preis	Mehrpreis f. Schmelzwasserkast.
	hoch cm	breit cm	tief cm	ca. Ltr.	RM	RM
881/5 Ziso	88	44	42	42	**49.—**	**3.—**
881/5 E	88	44	42	42	**60.—**	**3.—**

Haushalteisschrank

Nr. 951/5 E · Nr. 1051/5 E

Eiskasten mit Doppelrost, herausnehmbar, aus Stahlblech, im Vollbade verzinkt. Beschläge verchromt. Mit 2 Rostauflagen mit je 2 halben Holzrosten. Auf Wunsch mit Schmelzwasserkasten mit Ablaßhahn.

Nr. 1051 mit seitlichen Luftschächten.

Außen weiße Öllackierung.

Auskleidung Stahlblech, weiß emailliert.

Nr.	Außenmaße			Nutzraum	Preis	Mehrpreis f. Schmelzwasserkast.
	hoch cm	breit cm	tief cm	ca. Ltr.	RM	RM
951/5 E	95	49	47,5	55	**78.—**	**3.50**
1051/5 E	105	54	50,5	78	**96.—**	**4.50**

Abb. 4

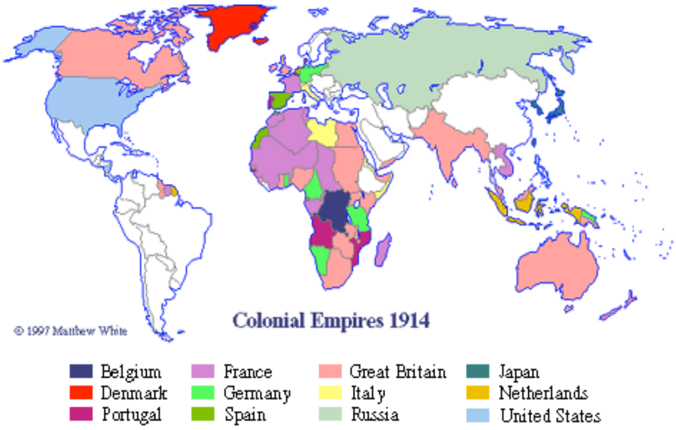


Abb. 6

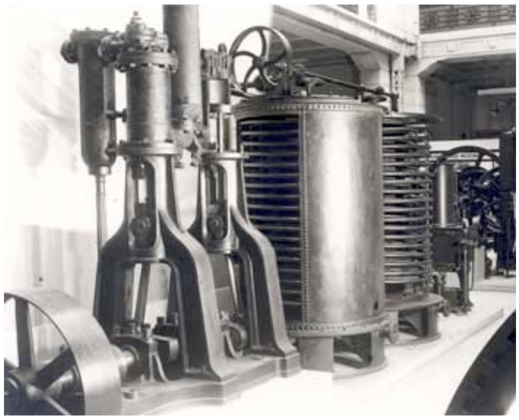


Abb. 7

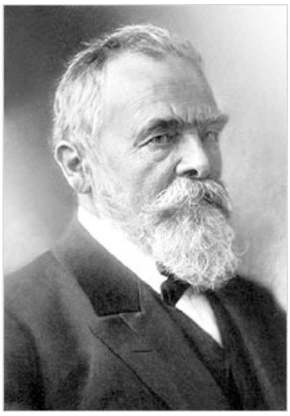


Abb. 8

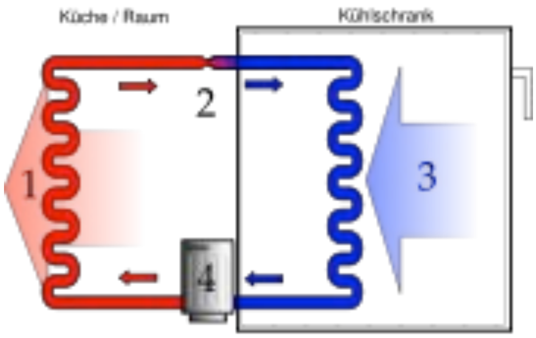


Abb. 9

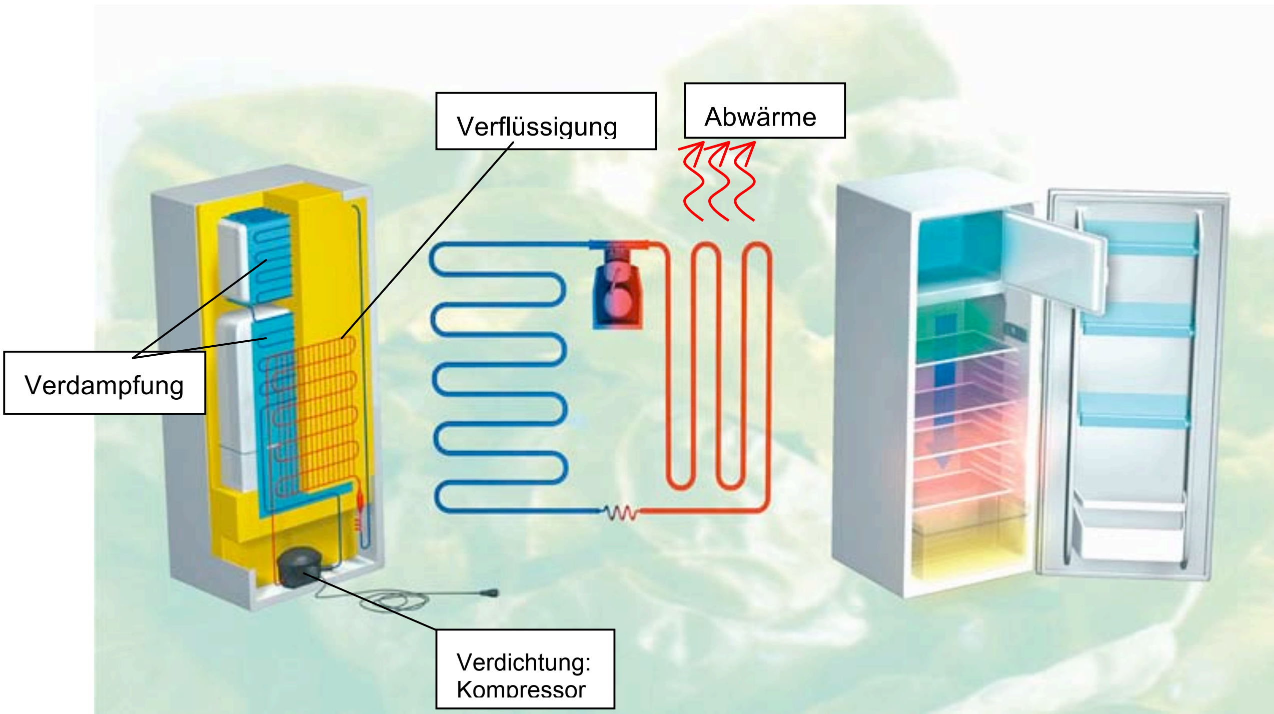


Abb. 10

Bildmaterial zu 5.2.2. Eisherstellung

Abb. 11

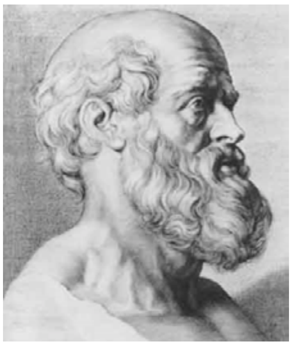


Abb. 12

Abb. 13

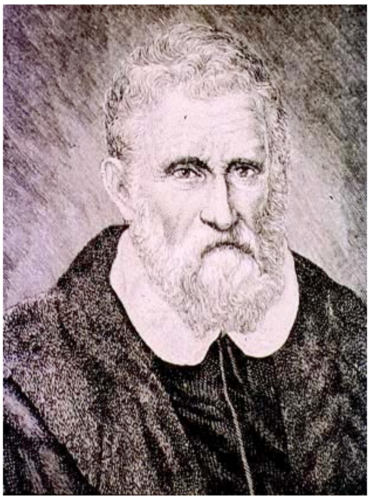


Abb. 14

Abb. 15

Abb. 16

Abb. 17

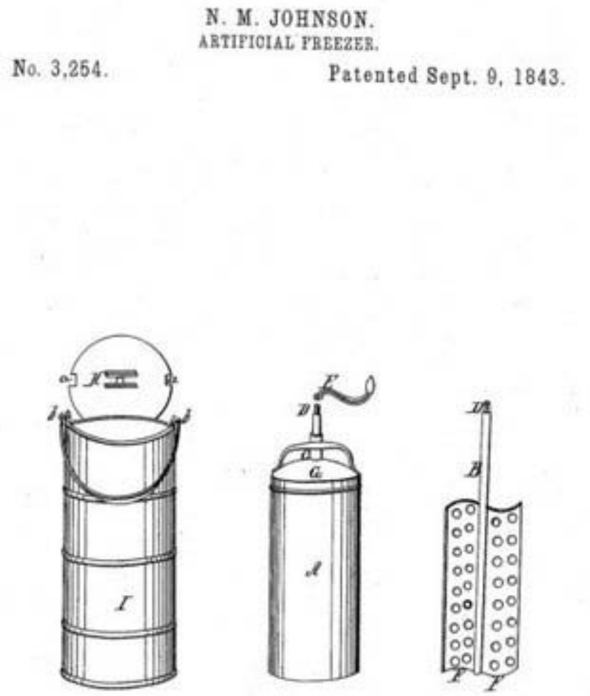


Abb. 22

Abb. 23

liquification
off-heat
evaporation
compression compressor

container with ice cream
container with ice-salt mixture

9. Methodical and Didactical Hints

9.1. The Reflection Corner – Worth Knowing about the Method

Provided Assistance in 'Talking about Physics'

Experience and numerous studies have shown that students learn very little about the nature of science when it is hidden in the teaching contents or processes. Even to act as a scientist or to learn about the history of science only in rare cases leads to reducing pupils' naive views about science.
Only when it is certain that they reflect their actions explicitly in the generalized context of scientific processes, it can also be assumed that they learn something about the nature of science. The same is true for any other sources, which students can learn from in the classroom, potentially on the nature of science.

The Reflection Corner is a methodological tool, which will facilitate for students systematic talking about the role, function, conditions and characteristics of natural science, scientific knowledge and its production.

If students are prompted to think about such abstract things in a normal classroom context, they will speak from experience in the form of their own specific learning acts ("First I've read the task ..."), and will recapitulate acts of historical scientists or they are simply overwhelmed. They need help to be able to understand their own actions and historical examples as actions of researchers and then being able to generalize. **With appropriate questions** that can be derived from the classroom and its contents and certain aspects of science can be addressed, the reflection process is stimulated. Naive ideas can be recognized by the teacher and questioned **directly related to the teaching**.

Integration into Teaching

Material:
The issues and ideas of students should be recorded permanently as common teaching result. For that purpose a poster, a bulletin board or a whiteboard may be used.

Procedure:
To guide the discussion ABOUT sciences and to get students used to it in the following hours, there should be **a permanent issue**, which ritualizes entry into the reflection. Only then, particular aspects of the nature of science are to be identified with specific questions.

Proposals for long-term issues:
We talk ABOUT science:

How do scientists work?
How to acquire new knowledge in science?
What is typical for natural sciences?
How does science operate?
etc...

How should I know?
Relevant aspects of the nature of science easy accessible for students are fully described and the appropriate learning opportunities are illustrated.

What are the students to know?
This teaching material can ensure that pupils have all the necessary information at hand before answering the questions, as they are for example involved in research themselves in class, (in the sense of inquiry learning).

- simulate real research processes (hold a conference, give interviews, write researchers' diaries, etc.).
- understand research processes of historical scientists (e.g. work on replicas, test conjectures of historical scientists, etc.).
- experience lots of historical scholars and the conditions of their time.

This means that you as a teacher and together with students can use the following things in order to try and get ideas:

- own specific teaching acts
- actions of historical scientists
- historical context (biographies of individual scientists, and social / political / economic / religious influences of and to natural sciences)

This can look as follows:

Part 1:
First, there is a collection of ideas and an open discussion of selected permanent problems. This will include questions such as:

What have you learned today about how scientists work, how one can achieve new knowledge in science / etc.

... if you think about what you have done today?

> Possible suggestions by the teacher:
> *You have solved the problem in very different ways / ... you had different results / ... you have argued / ... you needed to establish your own presumption / you needed to use your previous knowledge ... / ... you had an unexpected result / ... wanted urgently that your hypothesis is confirmed / ...*

... if you remember how XXX (for example, Carl Linde or Mohammed Bah Abba) has proceeded?

> Possible suggestions by the teacher:
> *XXX investigated traditional craft techniques / ... made assumptions / … applied scientific findings about thermodynamic cycles / ... looked for simple and cost effective solutions for his problems /... wrote scientific articles / ... was professor, inventor, and businessman at the same time / ... constructed technical devices / ...improved known metods on a scientific basis / ... examined function and effectiveness of his inventions with great accuracy / ...*

... If you think about what you have learned about XXX (e.g.* Carl Linde or Mohammed Bah Abba*) and his time?

> Possible suggestions by the teacher:
> *Europeans' supply with foodstuff from the colonies required effective cooling during the transport /... the spoilage of food caused by inadequate cooling tightens starvation in the Third World / ... the mass production of beer required vast cooling capacities / scientists are highly interested in the properties of substances at very low temperatures / ... the insufficient electricity supply in Third World countries prevents the use of modern technology / ... the introduction of new techniques must not take place at the expense of traditional jobs / …*

Students´ ideas in this part should be documented. If they have absolutely no ideas, it is appropriate to ask individual proposals for discussion, as shown in the above example. In selected ideas there should be a discussion about whether they are more typical of the

traditional classroom or in general for natural sciences as well.
When the appropriate occasions have not occurred yet in part 1, now a more goal-oriented part in the discussion will follow.

Part 2: Targeted Questions

To give students opportunities to achieve the learning objectives presented on the nature of science, now a brief phase is included in which particular issues are important. These have specific characteristics of science to the fore that can be learned with the case study. Learning opportunities could be special student activities, original historical texts or fictitious statements, and biographical and historical explanations by the teacher.
Both questioning and central ideas of pupils should be documented.

Example 1:

In the case study, students reproduce in different groups how a scientist carries out a large amount of experiments and documents them and then establishes a presumption of laws.
A possible reflection question may be:
We have seen that XXX has carried out many experiments first and then established a presumption. Can we acquire scientific knowledge in different ways? Are his/her conclusions compulsory or are there different options?

Example 2:

A scientist describes in a fictitious letter, how he presented his findings to business leaders, but these doubted the economic applicability.
A possible reflection question may be:
We have seen that the value and usefulness of XXX's results have not yet been accepted. What do the technical proposals of a scientist / engineer have to do with whether businessmen accept his results? What makes “good” technical solutions?

The first example involves the idea that there is not a scientific approach and provides information on the inductive method, which can be distinguished from the deductive method with some help of the teacher.
The second example shows that scientists must justify to others and that quality criteria for scientific findings can be derived from their results.

9.2. Learning Circle

In the learning circles several stations are set up that are geared to a particular subject area. For the design of the stations the topic is broken down into smaller sections. All students work practically simultaneously towards the same learning objective, although they are busy with different tasks.
There is a distinction between "closed" and "open" learning circles.
The closed circle is characterized by its relating to others. It is therefore necessary that the participants start at the first station and stop at the last. This form has the disadvantage that the issue of freedom of choice is eliminated from individual stations, and that individual stations can be crowded.
The open learning cycle provides the students, however, the opportunity to choose a station and to spend as much time on it as they want. Since many students often choose the first one according to their individual learning style, the problem of this station is usually solved. This increases the attractiveness of other stations and the readiness for more complex issues and not to immediately move on to the next station.

Working with the learning cycle is:

- selecting a learning area independently and then deal with it.
- applying individual strengths and talents and to focus intensively on topics

working in various social forms, with the "will to complement each other" and have the “lone fighter syndrome” be in the background.

choosing its own chronology depending on the priority and complexity of the task.

10. Research & Evaluation Results

11. Thematic Resources

12. References

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