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Teaching Science in Europe

ENGLISH

SCIENCE ON STAGE Deutschland

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Teaching Science in Europe

What European teachers can learn from each other

Under the guidance of the non-profit association Science on Stage Deutschland e.V. (SonSD), forty teachers from fifteen European countries discussed concepts and materials for science lessons.

SCIENCE ON STAGE Deutschland

Contents

Teaching Science in Europe

An international teachers' workshop – organised by the association Science on Stage Deutschland e.V.

Europe is merging – also in terms of youth education, which has largely been an issue of national sovereignty so far. This is a very positive development.

For some years now, international studies comparing different countries, such as TIMSS and PISA, have described advantages and shortcomings in science education. Such rankings are a major reason for looking at national and European education process variables in more detail.

Looking beyond national boundaries, examples of 'good practice', unusual viewpoints and surprising solutions can counteract problematic situations within national education systems. However, these remedies only work if own education scripts are disclosed, analysed and modified in view of this European experience.

For this purpose, the association Science on Stage Deutschland e.V. has coordinated the German participation in this European work process since 2000. The association brings insights gained at European conferences to the federal states of Germany. On the other hand, it takes German experiences and views back to the European stage by

- selecting, supporting and accompanying the German participants and their projects at European festivals and symposia,
- organising national workshops in several phases and teacher-training sessions with European participation in between the festival dates, integrating them into pan-European conferences,
- publishing, distributing and discussing the results.

The teachers' workshop "Teaching Science in Europe" started with an event organised by the association, which took place at the Physics Centre of the German Physical Society in Bad Honnef near Bonn from 26th to 28th November 2004. (For follow-up conferences and participants, please refer to the back of this publication.) The international group of teachers – having to limit themselves – selected four topic areas for a productive European education dialogue, working towards scientific literacy:

- Teaching science in primary school
- Interdisciplinary teaching
- The role of the experiment in teaching science
- Astronomy in the classroom

All countries are increasingly committed to maintain and support our children's desire for discovery and their joy of recognition when they begin their formal school lives. Considerations regarding **Science in primary school** reveal how this goal can be achieved and how important reference points are to the everyday lives of children. Children still have a holistic and thus "undisciplined" view of the world. They ought to be introduced very carefully, applying a lot of discerning intelligence, to the division of research into specialist disciplines, which seems necessary from a scientific point of view. If we fail here, the children first lose interest and afterwards their ability to transfer their specialist knowledge, applying it to more complex contexts, or in everyday situations. **Interdisciplinary teaching,** topic of the second workshop, enables us to counteract the disintegration of our growing knowledge of the world into unrelated modules and partial knowledge.

Natural sciences are empirical and thrive on experiments. **The Role of the experiment in teaching science** involves a high level of didactic and methodical requirements. The experiment as the traditional question to nature needs to be based on a theory with sufficient substance. In addition, the scientific insights gained in school experiments – including more recent ones – can generally only be "second-hand". The third group of the European workshops examines how sustainable motivation and findings can nevertheless be achieved through school research activities.

Over the millennia, looking at the sky has been a major aspect of scientific thinking and philosophical interpretations of the world. Over the last few years, there has been growing public interest in fascinating images from the depth of the cosmos as well as new models of cosmological explanations provided by enormous progress in experimental astronomy. **Astronomy in the classroom** can make a significant contribution to the education of people and the culture of our societies.

All subject areas have an interdisciplinary leitmotif in common. Teachers, and to a much lesser extent researchers, are seen as the inventors of categorisations, subjects, objects, types of teaching and hierarchies, classes and canons. Good teaching, however, knows no boundaries between defined objects, as any topic might emerge at any time. Socrates talks about the animated mind, the *kat' ouron*, that goes "with the wind". Good teaching can therefore never solely rely on specialist knowledge. In this context, the dialogue at a European level proves to be as necessary as it is helpful. The cultural background is a main constitutional element in the process of science education. The dialogue across national borders links different ways of culturally-influenced thinking and working. It opens up the development of new methods, techniques and approaches beyond the traditional specialist areas, which break up conventional thought structures and introduce cross-disciplinary potentials.

The participating international groups used this working platform provided by the organiser – which at the same time offered intercultural exchange opportunities – with great enthusiasm to enlighten and enrich the house of European culture with "their" scientific windows on the world. The results outlined in the following publication can only show an incomplete picture of the subject-specific framework available to European teachers. The main gain lies in the continuous exchange of ideas and in the changes made in people's minds.

The organiser would like to thank the participants for their great commitment and wishes all teachers luck and success for their future work in local schools.

In order to include the reader in the ongoing dialogue, we would like to ask you to fill in the questionnaire at the end of this book and return it to us.

The programme and the publication of the results would not have been possible without the generous support of the initiative THINK ING. (an Initiative of the German Association of Metal and Electrical Industry Employers), the Andrea von Braun Foundation and the Wilhelm and Else Heraeus Foundation. All participants and the organisers are very grateful for this support!

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Science in primary school

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Teaching science in primary school is a wonderful challenge. Primary school children are very interested in nature and in their general environment. They want to learn how the world works. Therefore, teachers have to support them in their investigations and assist them in exploring the world.

The goal of this article is to help primary school teachers to create interesting lessons on science topics and to provide some examples for them. In this work, we outline important aspects of teaching science in primary school and give some hints about attractive and effective teaching methodologies.

Introduction and Motivation

As a teacher, you are the essential resource in the classroom and in charge of creating a dynamic learning environment. You have to be flexible and try to adapt, modify and enrich your science topics according to your learners' needs and the requirements of your school.

Consider yourself an instructional leader and guide and allow the pupils to include their own experiences in their learning. Your role is to question, probe, clarify, monitor, assist and otherwise encourage pupils to progress.

The learners are the stars in the classroom. Their experiences, their own perception and their questions are the source of your teaching – therefore their ideas are very valuable and important. It is important to encourage the learners to engage with the world, to investigate and to explore it creatively. Please always bear in mind that children are inventors, artists, researchers, discoverers and little philosophers.

Teaching method

Science helps us to understand how nature works. By collecting experiences from their general environment (physical, social, etc.) children have formed their own ideas/preconceptions concerning many physical, chemical or biological phenomena, even before they get into school. They are "forced" to do that by their need to predict or explain whatever happens around them even though most of the times these ideas are far from the scientific model.

In teaching science, teachers have to stimulate the leaners' interests and change preconceptions about science topics. It is widely known that students learn best when they are allowed to work out explanations for themselves over time through a variety of learning experiences. The learners add their own knowledge to these experiences and subsequently link new information with their previous knowledge. To help them make the connections between what they already know and new information, we have to follow five different stages – Engage, Explore, Explain, Elaborate and Evaluate.

Engage

Firstly, the learners have to engage with a question mentally. This starting point captures their interest and provides an opportunity for them to express what they know about the concept. They can articulate their own ideas/preconceptions about the topic.

Explore

The learners carry out hands-on activities that allow them to explore their concept of the topic. They grapple with the problem or the phenomenon and describe it in their own words. If they had misconceptions on the topic, this step tends to prove to them that their own ideas cannot explain a particular phenomenon.

Explain

After exploration, explanations and terms to describe what they have experienced must be provided. The significant aspect of this stage is that explanation follows experience.

The explanations are not provided by the teacher (most of the time). The learners reach their own conclusions because of the experiments. Hence, the explanation follows the experience, yet the learners try to reach conclusions on their own.

Elaborate

This stage provides opportunities for the learners to apply what they have learnt to new situations and so develop a deeper understanding. It is important for them to discuss and compare their ideas with each other.

Evaluate

The final part has a dual purpose: learners continue to develop their understanding, and they evaluate what they know at the same time. This is also the logical stage at which to assess the learners' understanding of the concept's proficiency.

Examples

The following examples give an insight into our work – either emphasising the importance of a methodological approach or highlighting ways of making science lessons more attractive and effective. They do not present full lessons but lesson components.

Air helps drinking!

Objectives:

→ To acquire the idea that air needs space.
→ To acquire the idea that you can only drink out of a bottle and a straw if air streams in to replace the water.

Procedure:

ENGAGE

It is useful to ask the pupils at the beginning of this experiment what they know about air and what they would like to know. This in turn helps to identify the children's specific interests and their potential misconceptions.

What I know about air:

→ *If there is no air, we cannot breathe.*
→ *Sometimes air can be so strong that houses are destroyed.*
→ *Air can stink (e.g. when my mom smokes a cigarette).*
→ *Air is outside, in nature.*
→ *Air can be warm or cold.*
→ *Air comes from the trees.*
→ *Air is like a good friend.*

What I want to know about air:

→ *Why can aeroplanes fly?*
→ *Why is air invisible?*
→ *What is air?*
→ *Why is air heavy and not light?*
→ *Why do we need air?*
→ *Why do we know that air exists?*

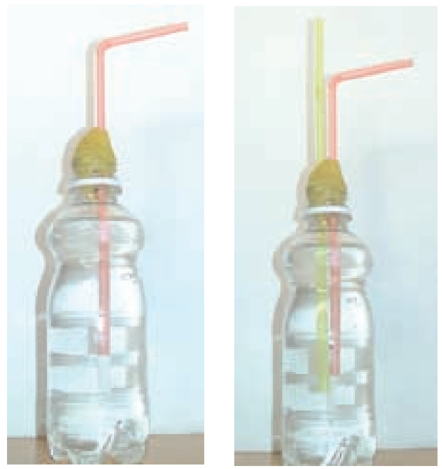
(Answers and questions were given by learners aged 8–10 years.)

EXPLORE

Informally discuss drinking with straws with the children.
Resources are handed out.
Children are asked to try and drink – but they fail.
Why is it impossible to drink? What can you do to succeed in drinking with the straw?

What you need: → bottle, straw, plasticine

What to do: → Fill up the bottle with water and dip the straw into it. Close the gap between the straw and the bottle by using the plasticine. No air should enter the bottle now!



←← resource 1
← a 2nd straw is added
(Source: Science on Stage Austria)

EXPLAIN

A second straw is handed out and added to the setup. The children are asked to suck, leaving the second straw open. Now they can drink with a straw.

Why is that? Air pressure itself makes it possible to drink water with a straw. If no air affects the liquid in the bottle, it is impossible to drink. When you suck on a straw, you reduce the air pressure in the straw. Air

pressure exerting a force on the liquid causes the upward movement of water within the straw and the water ends up in your mouth.
In the first experiment, the bottle was sealed up and no exterior air pressure was able to impact on the water in the bottle. If there is no balance in pressure, you cannot drink anything with a straw.
Air sucked in through the straw has to be replaced by air coming in from the new straw.

ELABORATE

Let them "play" with the device (leaving the second straw open, close it, ...).
Maybe they can find various other possibilities to make drinking possible from the initial resource (e.g. by removing the plasticine, by squeezing the bottle, by pricking a hole into the bottle with a needle...).
Introduce example of collapsing juice box.

EVALUATE

Do you know why and when you can use a straw for drinking?

A journey to the Sun

We want to introduce a wonderful and very interesting Italian project called Cielo! (Sky above!) to you. It is a web site released in cooperation between the INAF Observatory of Padua and the Educational department of the Municipality of Bologna.
"Cielo!" ("Sky above!") is a presentation of a didactical course that can be downloaded from the web site of the Observatory of Padua (www.polare.it or www.astro2000.org). The topic is science, with an emphasis on Astronomy and Physics. The target group: Teachers of learners in the age group 5 – 13. Cielo! is divided into units with specific aims, materials and contents.
Have a look at (a part of) module 1 "A journey to the Sun"!

Objectives:

- → To acquire the idea that the Sun has no eyes, no mouth and no rays.
- → To acquire the idea that the Earth and the Sun are spherical in shape.
- → To acquire some manual skills (knowing how to handle plasticine, salt dough...).

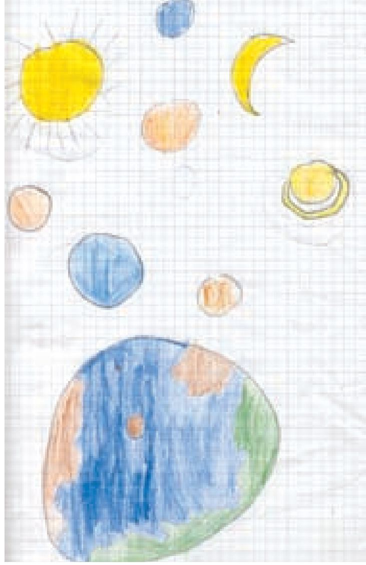
Procedure:

ENGAGE

Open discussion: What do you think you will see during the journey to the Sun? What is your image of the Sun?

It is useful to start the activity with a free conversation, which allows the identification of the children's misconceptions.

- → *The Earth might be round, and I imagine the Moon to be sometimes half, sometimes full.*
- → *The Sun is round in shape and it has rays, the Moon is also round in shape.*
- → *The Moon is round in shape and it has a lot of holes.*



Before the trip, children draw how they imagine the Sun, the Earth, the Moon, the stars.
(source: Cielo! un percorso di astronomia e fisica)

EXPLORE

Show PowerPoint presentation.
The PowerPoint presentation can be found under www.polare.it. Select the *Heavens above!* project section and "Presentations"
or at www.astro2000.org. The text could be:

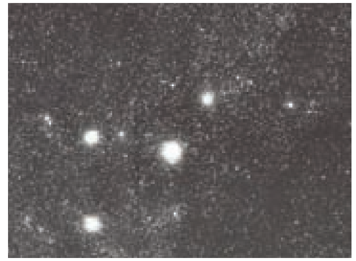
"Are you ready? Now sit down, we turn off the light and are ready for take off..."

"...but how high are we by now? ...

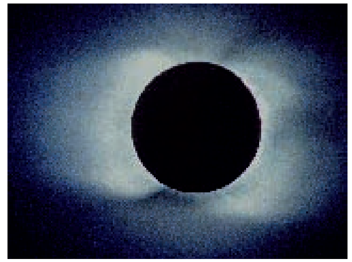
...even higher and here you are – Europe..

... even higher and here you are – the Earth, but there are clouds, we are outside our... what is it called?"

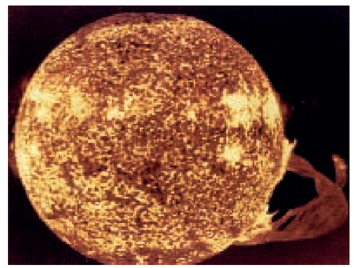
"... Now a long journey towards the Sun begins, the Earth moves further and further away and the sky gets darker and darker, but we can see the stars!!...."



"...and here is the Sun, first we keep it covered, otherwise it bothers our eyes, we have travelled too much in the darkness, but now, here you are, we can see it very well... but, how weird, it does not have rays. I wonder why they have not drawn the rays on the Sun!"



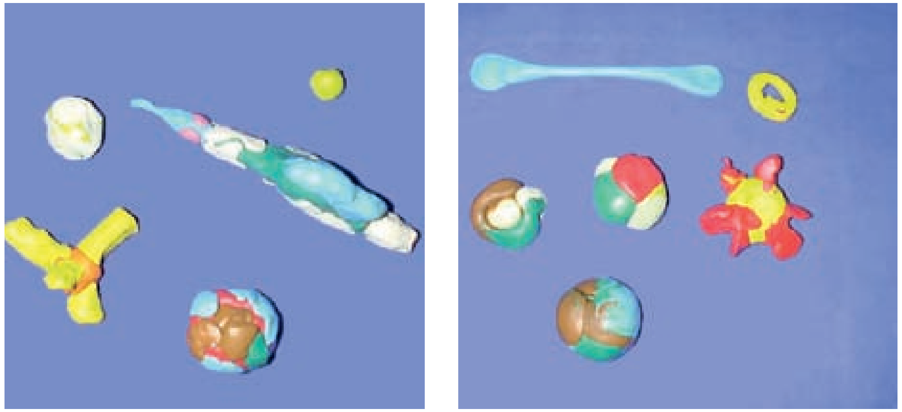
"... Oh, it is getting warmer and warmer..."



(Pictures are taken from the PowerPoint presentation under www.astro2000.org, picture-source: NASA)

EXPLAIN

Ask the children to represent the Earth and the Sun by using plasticine or salt dough.



Samples of Sun, Earth, Moon, Stars representations. The other objects in the pictures present the space shuttle. (source: Cielo! un percorso di astronomia e fisica)

ELABORATE

What did you like about the journey?
(Let them draw their impressions.)

Whatever context the trip is set in, the image that strikes children most is always the same: the Sun, the "spurts".
(source: Cielo! un percorso di astronomia e fisica)

EVALUATE

Children are now asked to represent the Earth and the Sun according to how they have seen them in the "fantastic" journey and by using the same materials they used in the beginning.

Representations of the Sun made by the children after the activity.
(source: Cielo! un percorso di astronomia e fisica)

Build your own copy machine!

Objective:

Learners use a CD cover as a semipermeable mirror and learn to know the position of the mirror image. They can draw a copy of a picture by using the mirror image behind the CD cover.

Procedure:

ENGAGE

Starting questions must tie in with experiences from children's general environment.
Where can you find the mirror image? Is it in the mirror, is it behind it?
Does a child in the mirror look like a child behind a window or does it look like a child on a photo?
A mirror creates a copy of a drawing. How can you obtain this copy as a real object?

EXPLORE

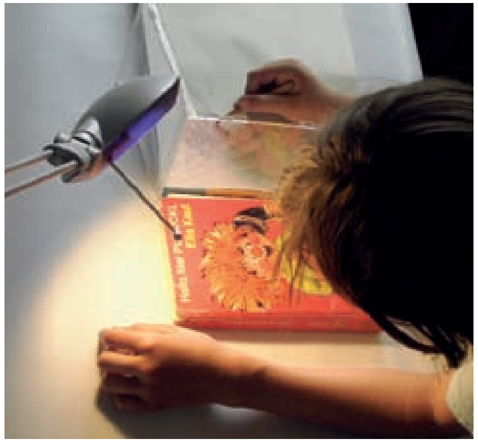
Resources are handed out and the following experiment can be done by the pupils on their own. (The teacher assists them in setting up the experiment.)

What you need:

- CD cover, artwork, sheet of paper, pencils, lamp

What to do:

- Put the open CD cover on the table in an upright position. (You can fasten it by using blocks.)
- Position the artwork on one side of the mirror and illuminate it with the lamp.



(source: www.turmdersinne.de)

- Put the sheet of blank paper on the other (darker) side.
- Look through the CD cover and you will see the mirror image. It seems to be exactly on the blank paper.

EXPLAIN

The mirror image seems to be behind the mirror and thus lies on the blank sheet of paper. If a point of the artwork is further away from the mirror, it is the same with the "mirrored" point. The initial artwork and the mirror image are of the same size.

In more detail:
The mirrored picture of a point is at the same distance to the mirror as the original point. The connecting line between these two points is at right angles to the mirror area.

ELABORATE

Pupils investigate which illumination of the mirror image enables them to see most clearly. (The artwork must be illuminated very brightly, the blank paper should be in the darker zone.)

The learners definitely need help in adjusting all the individual parts to make sure that the mirror image is positioned directly on the paper.

Artwork and paper must be in-plane. The artwork should be very close to the semipermeable mirror. The mirror must be exactly perpendicular to the plane. Otherwise the mirror image will not be in the correct position. A discrepancy of as little as 1° causes the mirror image to levitate about 4mm above or below the paper at a distance of 10cm.
Left-handed children may work with a side-inverted setup of the experiment.

EVALUATE

Learners copy the artwork by using their own copy machine!

Food chain

Objective:

Enable children to understand that grasshoppers are useful animals.

Procedure:

ENGAGE

"Grasshoppers are not useful."
Are you for or against this statement? Justify your answer!

A high percentage of primary school children believe that grasshoppers are harmful.

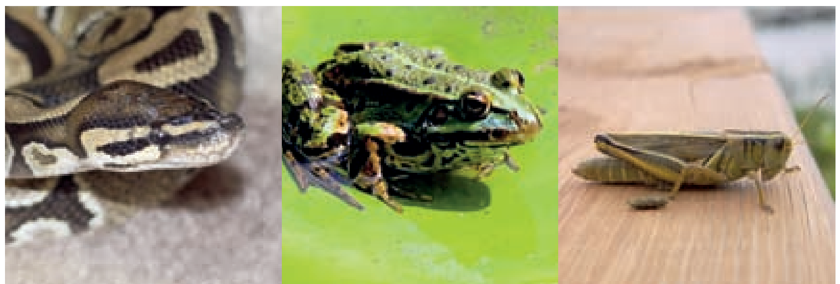
EXPLORE

Role play:
Some children pretend to be the grasshoppers, others take the roles of frogs and the rest are snakes.

- Imagine an island only populated with grasshoppers, frogs and snakes and play: who eats whom.
- Now imagine that a disease kills all the grasshoppers on the island. Play what is happening next.

All pupils know that frogs eat grasshoppers and that snakes eat frogs.

(source: Jeff Williams/morguefile.com, sxc.hu, P. Winberg/morguefile.com)



They realise through role play that frogs would die without grasshoppers and subsequently the snakes would die without frogs.

EXPLAIN

"Now, do you really believe that grasshoppers are not useful?"

ELABORATE

Discuss various other kinds of food chains.

EVALUATE

Compare your conclusion with your previous opinion. What led to the change in your opinion?

The boiling point of water

Objective:

The temperature of water does not increase linearly when heated.

Procedure:

ENGAGE

Hypothetical experiment: We heat a certain amount of water for 12 minutes. The initial water temperature is 20° C. After 1 minute, the temperature rises to 31° C. What is going to happen next? Complete the table.

A high percentage of primary school learners would complete the table in as follows:

time (min)	0'	1'	2'	3'	4'	5'	6'	7'	8'	9'	10'	11'	12'
Tempera-ture (°C)	20°	31°	42°	53°	64°	75°	86°	97°	108°	119°	130°	141°	152°

Heat changes the properties of water. If we add enough heat to water in its solid form (ice), it will change its state of matter to become a liquid. We call this melting. If more heat is added, the liquid will change to gas (water vapour). When enough vapour forms – with the pressure of the vapour equalling the pressure of the atmosphere above the water – the vapour can then push the air above the container away and allow vapour bubbles to be released. We call this process boiling. Water in an open beaker does not get hotter than its boiling point.

In more detail:

In a liquid, the molecules are packed closely together, enabling many random movements as molecules slip past each other. As liquid water is heated, the temperature increases. With the temperature increase, kinetic energy increases, causing an increase in molecular motion (vibrations and molecules slipping past each other). Eventually, molecular motion becomes so intense that the forces of attraction between the molecules (i.e. the hydrogen bonds) are disrupted and the molecules break free from the liquid and turn into a gas. At boiling point, the liquid turns into a gas. The molecules are not in contact with each other in the gaseous state.

EXPLORE

Learners carry out the real experiment and write down their measurement data.

The main intention of this step is to trigger a cognitive conflict between what the learners have believed until now and what they explore. The idea is to lead them to a cognitive change caused by the scientific model.

EXPLAIN

Compare the temperature in the two tables!

ELABORATE

Conclusion: What is happening to the water temperature after some minutes?

EVALUATE

What did you believe at first? What do you believe know? What made you change your belief?

Let's observe the Sun!

Objective:

This activity seems to be outside any traditional programme, but it tends to eliminate one of the problems we often face when talking to children about the Sun – they think that the Sun is perfect, immutable and stable.

This activity allows us to see the object of our observation in the right light: the Sun is a star.

The activity is started with a "false" Internet research: An appropriate server for the learners' Internet research is prepared. The objective of this part of the activity is to achieve interdisciplinary, cognitive learning: particularly in the subjects German, English, mathematics, technology and informatics.

Procedure:

ENGAGE

Comprehensive discussion with the learners to understand what they expect from looking at the Sun.

The initial discussion is extremely important, enabling us to examine the children's expectations towards an astronomic observation, leading to an improved didactic intervention by bearing in mind these expectations. We can also try to steer the learners' expectations towards a more scientific approach. Another outcome is the introduction of a hypothesis, which they will verify themselves using the following observation (the hypothesis has to be explained in detail).

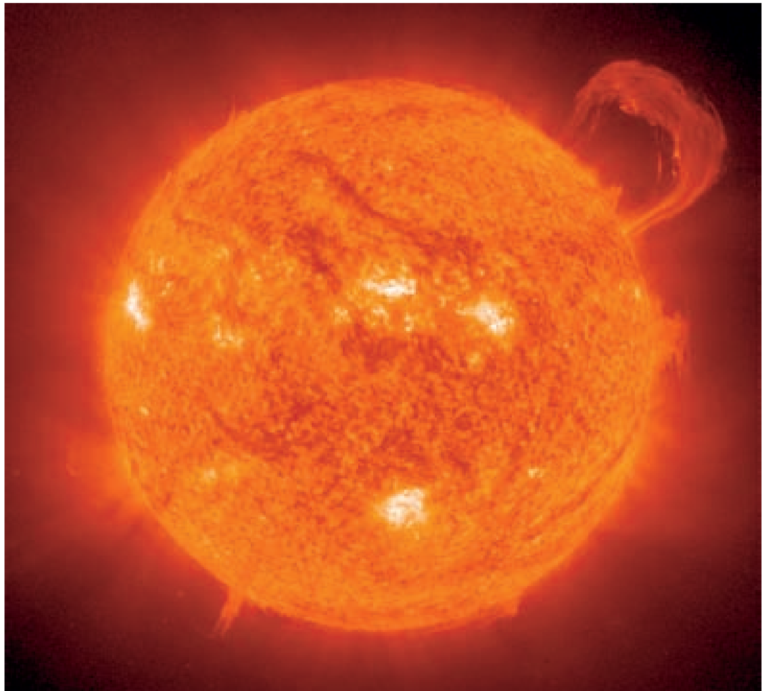
EXPLORE

An initial observation with binoculars, followed by reading Galileo's text (e.g. http://mintaka.sdsu.edu/GF/vision/Welser.html).

Description of the setup:

It is necessary to position the binoculars on a tripod to stop the device from moving . Then cover one of the two oculars to allow the sunlight to enter through the other ocular. Envelope the binoculars with black cardboard in order to project a well-defined shadow zone to the floor. Direct the light spot of the Sun to a white sheet. At this stage, the learners can start with their observations. It is beneficial to do this first part in small groups. At the end, the children should be invited to note their observations on a sheet of paper and maybe represent their observations with drawings (it may occur that learners claim they did not see anything – for that reason the initial discussion is important).
The next stage is particularly important. Read Galileo's text – first individually and then in groups. It is possible to understand what Galileo saw and to compare it with the learners' observations.
This will invite the children to continue with another observation of the Sun's surface.

Courtesy NASA/JPL-Caltech



EXPLAIN

A second observation with binoculars.

This new observation enables the learners to verify the presence of tiny spots on the surface of the sheet. Let them draw the image they see. You may want to prepare little paper disks with the same size of the image of the Sun as the base for the children to draw the dark spots.

ELABORATE

A third observation – three hours later.

After three hours, we repeat the observation and compare the differences of the new images.

EVALUATE

A final Internet-based test to find out what space satellites see when looking at the Sun.

Formative test: with available, familiar Internet web sites. Using the search engine Google, the learners are asked to look for images of Sun spots – if possible from the same day as their observation (for example: http://sohowww.nascom.nasa.gov/). This comparison is the end of the activity.

The interdisciplinary approach of teaching science in Europe

B

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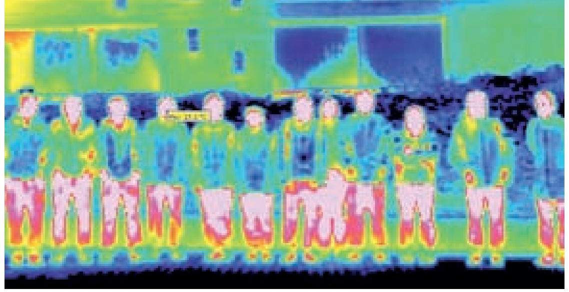
Today's society is in fast economic and scientific flux. Therefore, the perceptions of natural science play a decisive role: they revolutionise all spheres of human life – people's environment as well as their culture. The industrial nations – to a large extent responsible for developments – adopt an exposed position in this context. On the one hand, they are dependent on the capability of natural science research as well as education and on the other hand they influence all spheres of scientific approaches.

In all European countries, the scientific approaches change independently from each other, bringing forward an interdisciplinary way of research. Managers of education have been confronted with the idea of reproducing this structure in basic- and higher education in our European school systems.

Pupils' experiment
(Picture taken at Science on Stage 2005 in Geneva)



Thermography of a science class

So far rather unnoticed, an interdisciplinary approach to natural science education has been established in schools – partly as a result of convincing arguments and partly as a makeshift solution triggered by teacher shortages in a special subject. A comparison of the results and teaching methods at a European level may help to avoid errors and achieve synergies.

The aim of this article is to provide a basis for a common curriculum of interdisciplinary science teaching, being aware of the importance of systematically acquired knowledge in natural science.

Is Science interdisciplinary per se?

At first glance, the traditional science disciplines taught in schools differ considerably. Physics, chemistry, biology, mathematics and geography deal with different subjects and apply a wide range of methods. However, we may find a common logic in natural sciences if we analyse the methods in detail: Phenomena of nature are observed and attempts are made to describe these phenomena as objectively as possible.

Searching for possible reasons is the next step: How can we explain the observations? – We need hypotheses that can be proven in experiments. From these experiments, we draw conclusions and estimate the probability of the individual hypothesis. The aim is the search for a "truth" which is established in laws of nature.

From this point of view, we could see our environment as a quantity of objects (animate or inanimate), which interact observing natural laws. A hierarchical systematic organisation of subjects seems to coincide more with the structure of the human brain rather than with nature. Thus, for lower grades, it seems to be a valid approach to give an overview of the scientific disciplines, their topics and methods first, summarising them in one subject. This should help the higher grades to understand complex questions and methods in all science disciplines more easily, because it resembles the daily work of most scientists, who have to apply methods from various disciplines. Interdisciplinary teaching supports the establishment of "Scientific Literacy".

Solar power station as a class project

The meaning of scientific literacy in the interdisciplinary approach

In a broader sense, "scientific literacy" refers to a person's ability to comprehend and handle key concepts and basic scientific principles. Such a person can understand scientific issues and applications, has a more or less clear worldview and uses scientific knowledge and scientific ways of thinking for individual and social purposes. There is no doubt that these are aspects of a promising and skilful background for those who have learnt to think and act in such a way. Consequently, we can describe scientific literacy as a component of an integrated personality and therefore as a factor that leads to active internalisation in our society in this Digital Age.

It seems that nowadays the majority of students has no particular interest in science. The connections between science and technology are weak and their perception of these links is somewhat cloudy. Or it may be difficult for them to explain everyday phenomena applying the relevant scientific laws, even if they have been taught recently. In a few words – a large number of learners perceives the world as too complicated to understand: Science is a remote topic for them. In our opinion, we should focus on how we offer scientific knowledge. The challenge is to overcome the individual learner's hesitations, enhancing the general level of interest in science and the awareness of it. All over Europe, there are clear impacts of using special teaching methods. Hence the obvious question is: Is interdisciplinary teaching of science a way to reach this target? Our answer is: Yes! One nature and one world are the objective base of teaching science. Are interdisciplinary science teaching and scientific literacy connected? In order to answer this question, let us try to find common characteristics.

- Both start with observing phenomena that occur in our world/environment and arouse curiosity.
- Both emphasise a better understanding of concepts and the development of an inquiring and independent mind when implemented as teaching strategies.
- Both stress the unity and diversity of science and try to integrate all aspects of scientific contents.

Moreover, the interdisciplinary way of teaching science and scientific literacy have both a medium-term and a final aim: Not only some of the students at school, but also the great majority of people have to interact with science in our modern times where we are surrounded by science and its applications. Wouldn't everybody agree that all educational models have this same final aim? — But to what extent does each of these models actually reach these objectives?

When should interdisciplinary teaching begin?

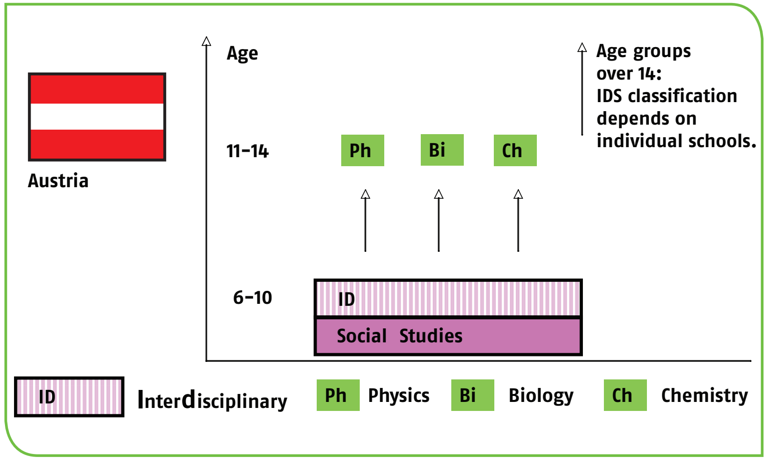
So far, every European school system is different. In most of the countries, a gentle interdisciplinary step can be recognised during the first years in school. Social studies or some kind of teaching natural science – depending on local conditions and not supported very well by experimental equipment – can be found in many countries, as you will see from the examples on the following pages. There are many encouraging

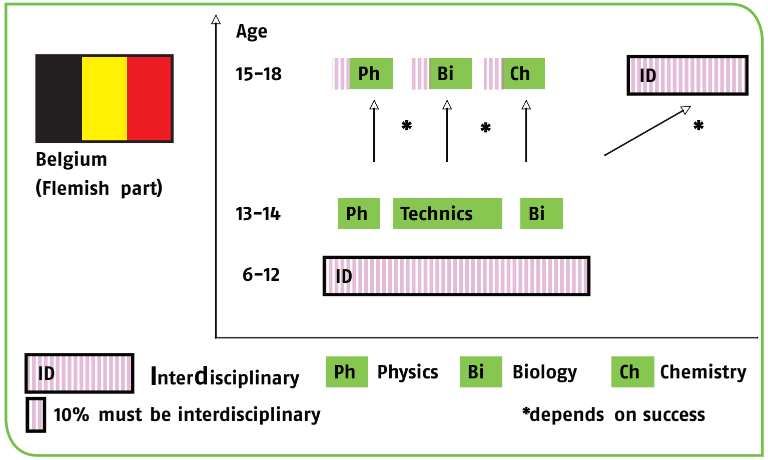
Young girls as "interdisciplinary scientists"

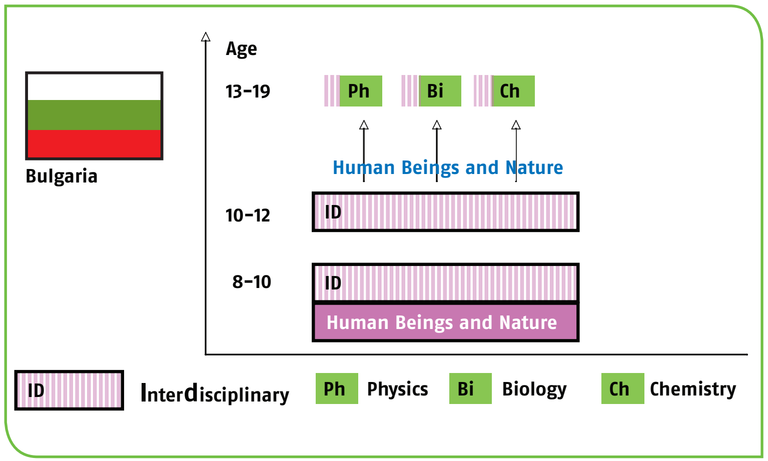
projects introducing teaching science at primary schools. But this is not our target group, because teacher training for this age group is not very close to science education in the current state. We hope that this age group will be involved in teaching science in future. Usually, science education starts in the age bracket 10 to 14. At this age, pupils have a holistic view and are very interested in phenomena of nature. Thus we suggest an interdisciplinary science education approach for this age group. But why does systematic science teaching – separating the subjects — still convince the majority of science teachers? Contrary to this teaching method, most of the pupils will not use a systematic access to science in their future life. However, because the other learners will need this systematic view for their ensuing education, a systematic science teaching approach should start in the following higher grades.

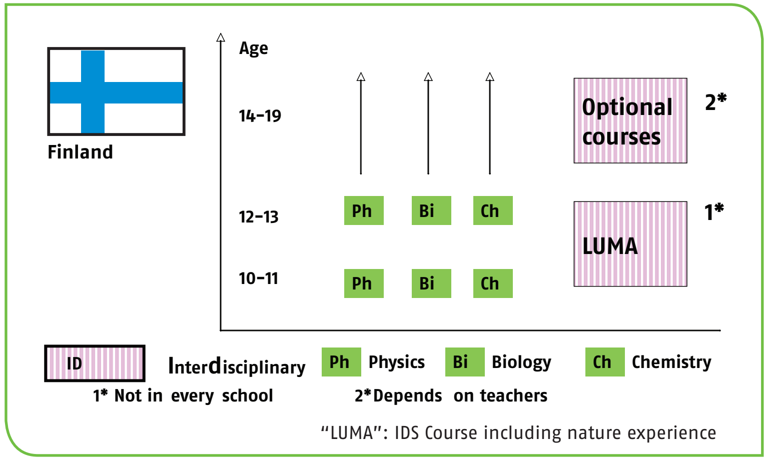
The current state of science teaching in European countries

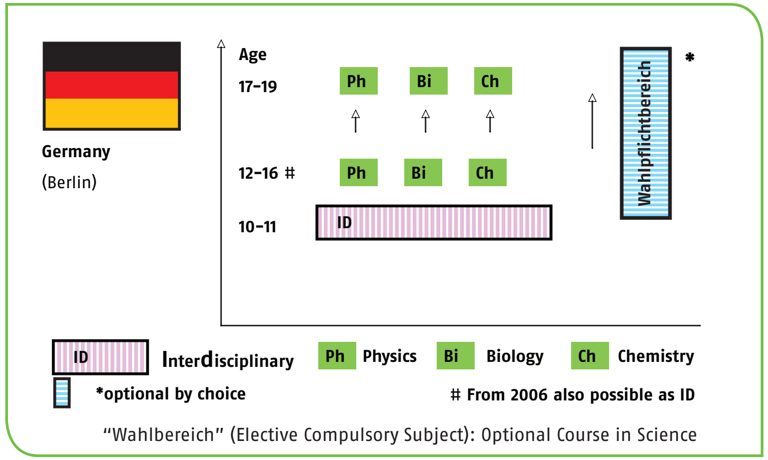
The following four pages attempt to give a short overview of science teaching structures in several European countries. Due to the variety of school types and educational backgrounds in each country, the intention is not to review an entire school system. However, for the majority of pupils in each country, the given examples can be applied as a general rule. In Germany, school systems vary from federal state to state. Therefore, only examples can be shown.

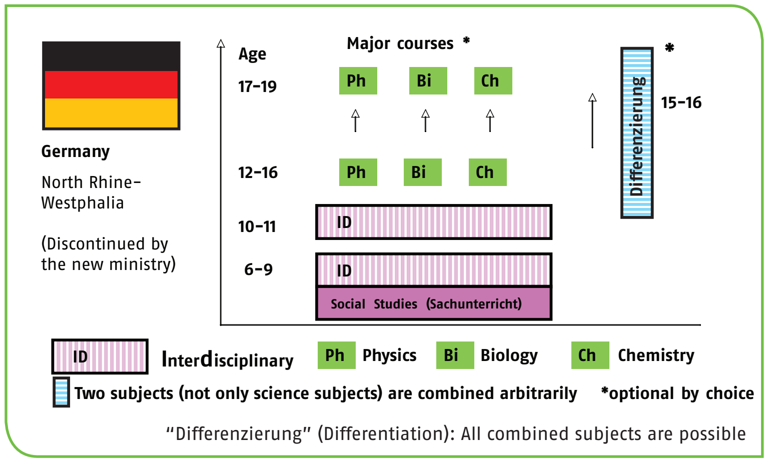

Austria
Age
Age groups over 14: IDS classification depends on individual schools.
11–14
Ph
Bi
Ch
6–10
ID
Social Studies
ID Interdisciplinary
Ph Physics
Bi Biology
Ch Chemistry

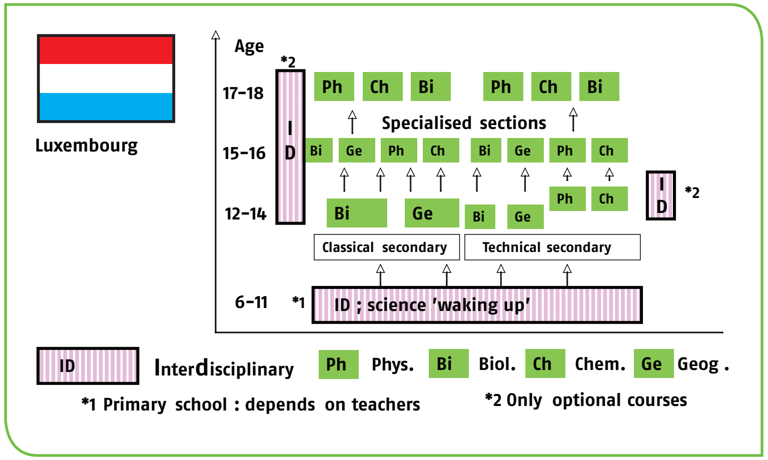

Belgium (Flemish part)
Age
15–18
Ph
Bi
Ch
ID
*
13–14
Ph
Technics
Bi
6–12
ID
ID Interdisciplinary
Ph Physics
Bi Biology
Ch Chemistry
10% must be interdisciplinary
*depends on success

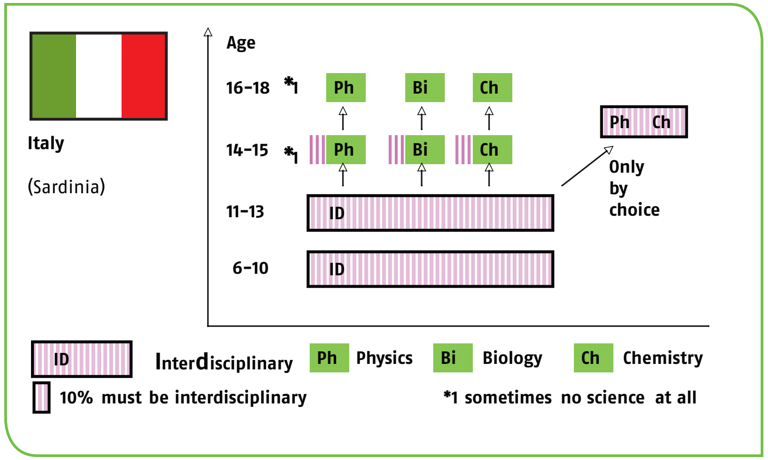

Bulgaria
Age
13–19
Ph
Bi
Ch
Human Beings and Nature
10–12
ID
8–10
ID
Human Beings and Nature
ID Interdisciplinary
Ph Physics
Bi Biology
Ch Chemistry

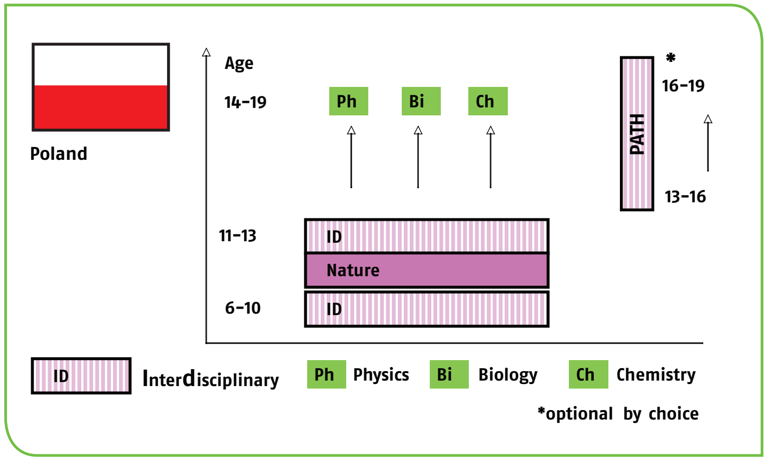

Finland
Age
14–19
Optional courses
2*
12–13
Ph
Bi
Ch
LUMA
1*
10–11
Ph
Bi
Ch
ID Interdisciplinary
Ph Physics
Bi Biology
Ch Chemistry
1* Not in every school
2*Depends on teachers
"LUMA": IDS Course including nature experience

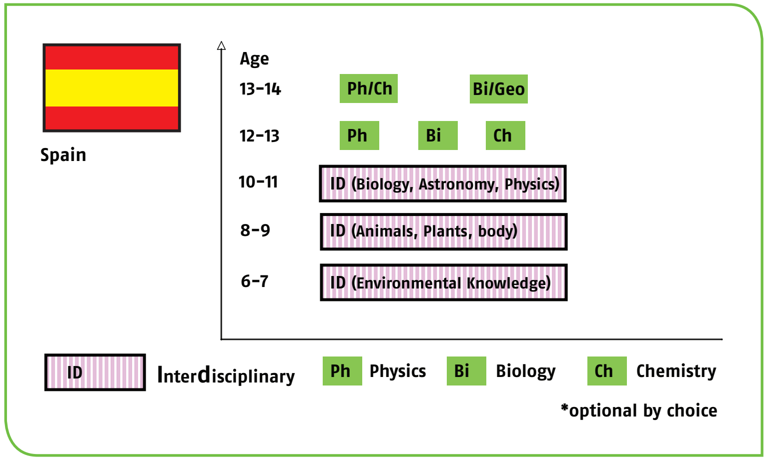

Germany
(Berlin)
Age
17–19
Ph
Bi
Ch
Wahlpflichtbereich
*
12–16 #
Ph
Bi
Ch
10–11
ID
ID Interdisciplinary
Ph Physics
Bi Biology
Ch Chemistry
*optional by choice
From 2006 also possible as ID
"Wahlbereich" (Elective Compulsory Subject): Optional Course in Science

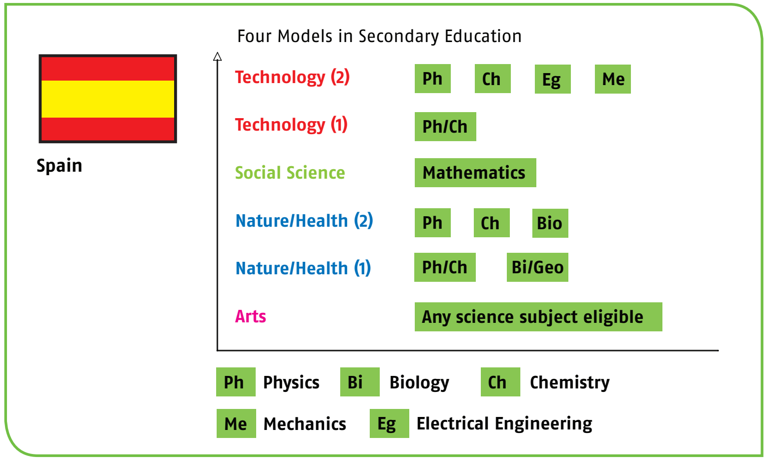

Germany
North Rhine-Westphalia
(Discontinued by the new ministry)
Age
Major courses *
17–19
Ph
Bi
Ch
Differenzierung
*
15–16
12–16
Ph
Bi
Ch
10–11
ID
6–9
ID
Social Studies (Sachunterricht)
ID Interdisciplinary
Ph Physics
Bi Biology
Ch Chemistry
Two subjects (not only science subjects) are combined arbitrarily
*optional by choice
"Differenzierung" (Differentiation): All combined subjects are possible

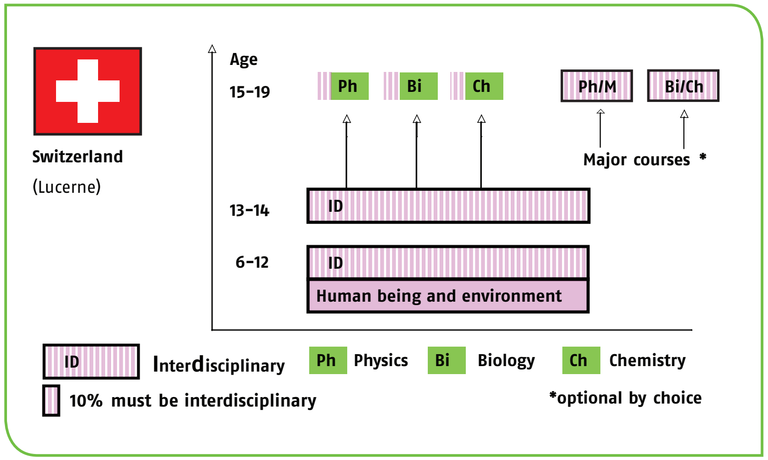

Luxembourg
Age
17-18
15-16
12-14
6-11
*2
I D
Ph Ch Bi
Ph Ch Bi
Specialised sections
Bi Ge Ph Ch
Bi Ge Ph Ch
Bi Ge
Bi Ge
Ph Ch
I D *2
Classical secondary
Technical secondary
*1 ID ; science 'waking up'
ID Interdisciplinary
Ph Phys.
Bi Biol.
Ch Chem.
Ge Geog .
*1 Primary school : depends on teachers
*2 Only optional courses


Italy
(Sardinia)
Age
16-18 *1
14-15 *1
11-13
6-10
Ph Bi Ch
Ph Bi Ch
ID
ID
Ph Ch
Only by choice
ID Interdisciplinary
Ph Physics
Bi Biology
Ch Chemistry
10% must be interdisciplinary
*1 sometimes no science at all


Poland
Age
14-19
11-13
6-10
Ph Bi Ch
ID
Nature
ID
PATH
* 16-19
13-16
ID Interdisciplinary
Ph Physics
Bi Biology
Ch Chemistry
*optional by choice


Spain
Age
13-14
12-13
10-11
8-9
6-7
Ph/Ch
Bi/Geo
Ph Bi Ch
ID (Biology, Astronomy, Physics)
ID (Animals, Plants, body)
ID (Environmental Knowledge)
ID Interdisciplinary
Ph Physics
Bi Biology
Ch Chemistry
*optional by choice


Spain
Four Models in Secondary Education
Technology (2)
Ph Ch Eg Me
Technology (1)
Ph/Ch
Social Science
Mathematics
Nature/Health (2)
Ph Ch Bio
Nature/Health (1)
Ph/Ch Bi/Geo
Arts
Any science subject eligible
Ph Physics
Bi Biology
Ch Chemistry
Me Mechanics
Eg Electrical Engineering


Switzerland
(Lucerne)
Age
15-19
13-14
6-12
Ph Bi Ch
Ph/M Bi/Ch
Major courses *
ID
ID
Human being and environment
ID Interdisciplinary
Ph Physics
Bi Biology
Ch Chemistry
10% must be interdisciplinary
*optional by choice

Preconditions for interdisciplinary science teaching

The following preconditions are important for the success of interdisciplinary teaching at different levels. (The special problem of age has been discussed before.)

1. Preconditions at schools

- A suitable infrastructure is very important. Together with books, Internet access and multimedia equipment are required in general.
- Experiments should play an important role. Suitable materials have to be easy to work with and should have as many connections to the real world as possible.
- It is extremely important that students can experiment on their own. They have to learn to work independently, taking responsibility for their experiments.
- To make this possible, timetables have to be adapted, allowing longer experimental phases.
- Team teaching is mandatory, especially when teachers are only trained in one scientific subject.

2. Preconditions in the curriculum and lesson plans

- A curriculum for interdisciplinary science should contain equivalent parts from biology, chemistry and physics as well as connections to other subjects without categorising the topics, because students at this age do not separate the subjects.
- Topics should be linked to students' surroundings. Initial phenomenological learning has to be transferred into more specialised learning later on. In addition, a smooth transition to the scientific subjects can be achieved.
- An interdisciplinary subject will require a larger time budget than a single scientific subject.

3. Preconditions in teacher training and qualification

- Courses in all three scientific subjects should be obligatory at university level, thus avoiding a focus on a single subject.
- Qualification courses have to be offered for teachers who are trained in only one scientific subject.

Competencies in interdisciplinary science teaching courses

The aim of an interdisciplinary science (IDS) course is to provide the pupils with a global view of natural processes and phenomena. An interdisciplinary science course has a cultural and a social purpose – the learners should be able to make informed decisions relating to science, technology, society, consumer choices, design and inquiring into phenomena.

An IDS course should be practical;
it should promote teamwork and autonomy.

Pupils should be able to:

- use different tools to collect, analyse and present data
- investigate using books, papers and the Internet
- use brainstorming and discussion
- develop and realise experiments
- use the computer.

An IDS course should teach the pupils to evaluate themselves and others.

Pupils should:

- evaluate the precision of measures
- be aware of the reliability of results
- find the sources of errors
- objectively and quantitatively assess and evaluate themselves and others.

An IDS course should teach the pupils to use methods of scientific research.
Pupils should be able to:

- observe natural processes with precision
- describe these processes using the appropriate vocabulary
- analyse the processes
- give an interpretation or develop a model
- formulate hypotheses
- realise experiments to verify these hypotheses
- articulate how interdisciplinary aspects of science are virtually everywhere.

Teaching methods and basic skills

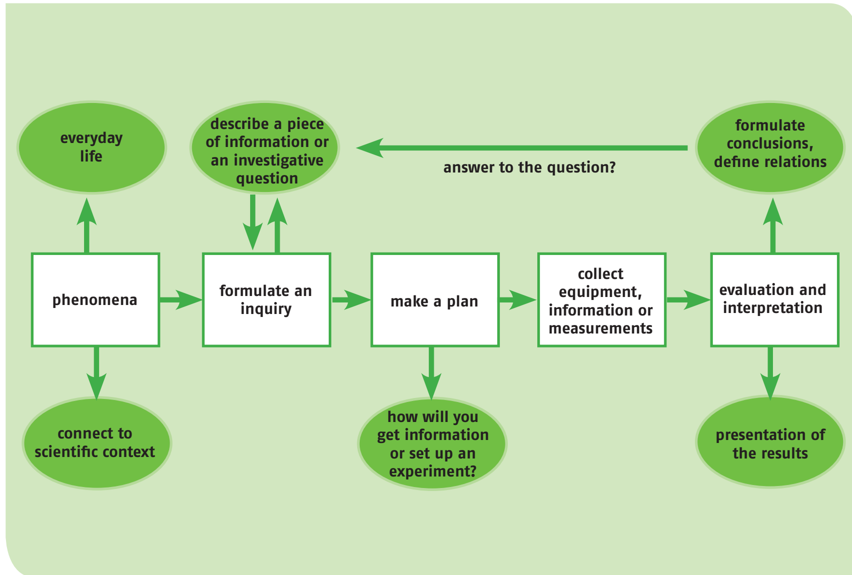
The interdisciplinary approach of teaching science emphasises scientific literacy – the knowledge and comprehension that learners need to understand science that they come across in everyday life.

The teaching method ought to be based on the following principles:

- Always start with existing knowledge and understanding.
- Pupils should build knowledge as much as possible rather than simply being at the receiving end.
- They should reflect on their learning, and learn the ability to control and to regulate their own learning.

Through a wide range of activities, learners are able to recognise the impact of science and technology on their everyday lives. Learning should incorporate basic inquiry skills and skills for handling information and communication as well as the development of a personal view on issues involving science. With activities that involve observing, classifying, experimenting, pattern seeking, comparing and contrasting ideas, the scientific understanding of the learners can be developed.

Flowchart: "Working with information" or "Implementing an investigation project":



Obstacles against an interdisciplinary approach

Discussing the experiences from several European countries, we found some serious obstacles for the establishment of IDS. However, the most severe error would be to ignore the problems. Teachers, authorities and parents have to be convinced of the overvalue of the IDS approach. One obstacle is presented by the teachers themselves as some of them are 'old- fashioned' and can only focus on their own subject(s), perhaps being doubtful because they did not study all subjects. Parents might share this fear because they are unfamiliar with interdisciplinary teaching and contents.

The other obstacle in school is missing equipment, especially good books and money. The last obstacle may be administrations which often have to adhere to education policy guidelines. It is possible that all three groups fear missing out on methods and facts of systematic learning in specific subjects.

Teaching Modules of IDS

The following pages will give some examples of possible IDS teaching modules. The themes selected include parts from biology, chemistry and physics in a balanced way. The contents are strongly connected to students´ surroundings and are close to their everyday lives, for example introducing "sensorial perceptions". "Mission to Mars" combines the fascination of space research with information about benefits such as satellites and technology. Other examples discussed were "environment and pollution", "metals and how to use them" or "astronomy". Because of space limitations, we will present them elsewhere (www.science-on-stage.de). Each theme has a reference- and contents structure as shown in the example "Mission to Mars".

Module 1	***Mission to Mars***
Module 2	***Sensorial perceptions***
Module 3	***The Sun and I***
Module 4	***My body and I***
Module 5	***Environment and pollution***
Module 6	***Metals and how to use them***
Module 7	***Astronomy***

Content of the module: Mission to Mars

Mission to Mars

Physics
- → Rocket technology – propulsion
- → Newton's laws – in space
- → Kepler's law
- → What is microgravity
- → Physical parameters in space
- → Our planetary system, Astronomy
- → Origin of the universe

Biology
- → How to grow plants in microgravity
- → Graviperception
- → Human body in space: Muscles, bones, nutrition, circulatory physiology
- → Radiation
- → Ecosystems

Chemistry
- → How to power a rocket
- → Purification of water and air
- → Composition of celestial bodies (nuclear fusion)

Computer science
- → Regulation (cybernetics)
- → Data processing

Mathematics
- → Navigation
- → Trajectories

Geography
- → Observation of the Earth

Engineering
- → Materials
- → Constructions

Module 1

Mission to Mars:
The Clinostat

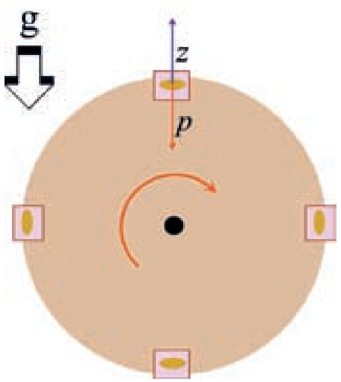


Fig. 1: Clinostat

"Mission to Mars" could function as a sample project of an interdisciplinary teaching module. Space missions have always been fascinating for young people as they have a high emotional appeal. As in any complex research project, contributions from all scientific and technical disciplines are mandatory. This provides the opportunity to develop interdisciplinary teaching units for several grades. Two examples for experiments from chemistry and physics and from biology and physics are given here.

Materials / Environment
A round wooden plate (diameter approx. 40 cm), motor (an old record player would also be suitable), some beans (seeds) ,filter paper, wire or string, water and a dark room

Background/Aim
The clinostat is a vertical centrifuge. During one revolution, it neutralises the direction of the gravity vector. If the gravisensing system of the specimen is slow (like in plants), the direction of natural gravity cannot be determined.

Follow these steps
Connect the motor to the wooden plate – similar to a turntable or a record player; however, the surface of the plate should be oriented vertically. Drill some holes near the edge and fix the beans and the filter paper using wire or string. Moisten the paper, switch the clinostat on and let it turn continuously for some days in a dark room. Deposit another bean on a wet piece of paper near the turntable in the same room. Water the beans daily.

What will happen?
You will notice that the beans germinate. The beans on the table grow their roots downwards, their shoots upwards; however, the roots and shoots of the beans on the clinostat grow in undefined directions. What happens if you repeat the experiment orienting the turntable horizontally (like a record player or a centrifuge)? You will add a centripetal (or centrifugal) acceleration (a_z) to the gravitational acceleration. It may be calculated from the radius (r) and the angular frequency (ω): $a_z = \omega^2 r$

Is the centripetal acceleration effective? How many *g* (1*g*=9.81 m/s²) can you achieve using an old record player at a radius of 0.13m and a rotational frequency of 78 min⁻¹?

Questions for discussion:
- ➔ Is gravity effective in the clinostat experiment?
- ➔ What is microgravity?
- ➔ Will beans grow in a greenhouse on Mars?

Module 1

Mission to Mars:
Launch a rocket

Materials
Disposable Pasteur pipette, hydrochloric acid, zinc, glass bottle, drilled plug, glass tube, dropping funnel, battery or power supply, push-button, wire, filament wire and a wooden plate

Background/Aim
This experiment shows the launch of a rocket using hydrogen and oxygen as propellants.

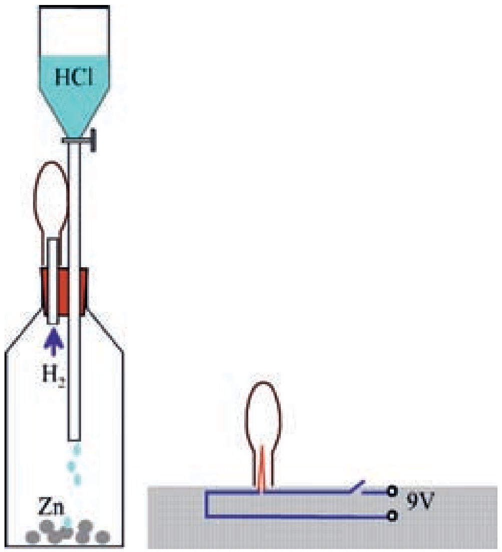


Fig. 2:
Rocket launch pad

Follow these steps

- Build Kipp's Apparatus as shown in the graph. Hydrochloric acid will react with zinc producing hydrogen and zinc chloride.
- Construct the "launch pad" from the wooden plate by mounting the battery, the pushbutton and the filament wire.
- Cut the Pasteur pipette and apply it to the Kipp's Apparatus to collect some hydrogen. We will use oxygen from the air.
- Apply the upper part of the Pasteur pipette to the filament wire and launch the rocket.

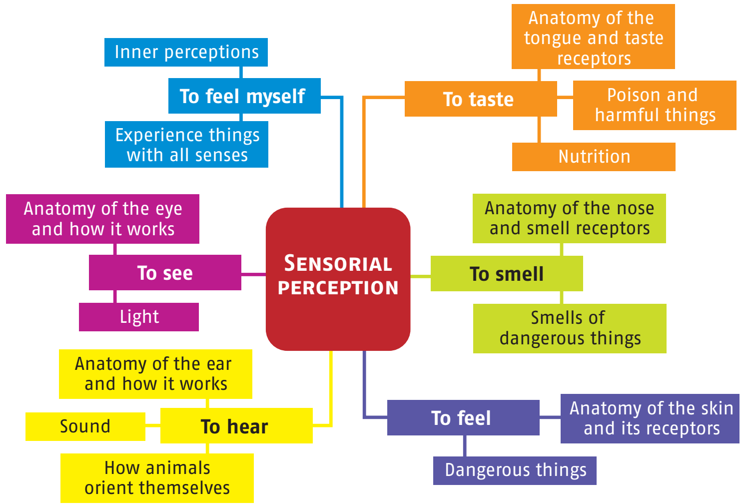
Questions

What powers a rocket? Why does a rocket fly? Why does it fly in space?

Module 2

Sensorial perceptions

Sensorial perceptions are particularly suitable for interdisciplinary science teaching as the topic itself is biological, but most of the experiments are of a chemical or physical nature. There are many interesting experiments that show how our senses work.



Module 2

Sensorial perceptions: The tongue and its taste receptors

Background/Aim

Our tongue can distinguish between four different tastes: sweet, salty, sour and bitter. The taste receptors are in different locations which the pupils can easily identify with this experiment.

Materials

4 cups with sugared water, salt water, coffee, vinegar, 1 drinking straw (cut into four pieces), a piece of bread

Follow these steps

- Dip the straw into one of the fluids and close it with your index finger.
- Let drops of the fluid fall onto different parts of your tongue. Observe where you can taste the flavour best.
- Eat a piece of bread to get rid of the taste and try another fluid.
- Draw the different taste zones into a picture of your tongue.

Fig. 3:
Taste experiments

Fig. 4:
The tongue

Fig. 5:
Fruits

Fig. 6:
Blindfold tasting

Module 2

Sensorial perceptions: Do we taste with our nose?

Background/Aim

When we have a cold and our nose is blocked, we cannot taste the food we eat.

Materials

Different types of food, such as: apple, carrot, potato, banana, cheese, ... (cut into small pieces), a knife, a fork or a spoon, a clothes-peg, a scarf to blindfold your partner

Follow these steps

- Close your partner's nose with the clothes peg and blindfold him / her.
- Then feed him with a piece of food and ask what it is.

The experiment works best if the test person does not know which types of food he / she will get and if the different food items are of similar consistency.

Module 2

Sensorial perceptions: Chasing restorations

Background/Aim

The colour of a body is normally perceived as a characteristic feature. It is astonishing that the perception of the same colour can vary significantly. By analysing and discovering restorations and retouchings realised with dyestuff that is different from the original – both in real and in self-made paintings – it can be shown that the perception of colour largely depends on the interaction between light and the molecules of the perceived object. Apparently, it is possible to demonstrate that the impression of a particular colour can be very different by using another sort of light: The determinant role of light in this process is obvious.

Materials

Mercury lamp, digital camera, video projector, laptop, painting or different dyestuff of the same colour, for example... (fill in normal paintbox materials)

Follow these steps

Pupils illuminate a painting or their own samples using a mercury lamp, filtered to transmit 365 nm, as the excitation light source. One part of the ultraviolet radiation is absorbed and released again with a

Choice of picture

Mercury Lamp

lower energy level within the visible spectrum: fluorescence. The pupils are then asked to take a photo with a digital camera.

Results

Different dyestuffs, which generally create almost the same colour impression in normal light, look different when using another type of light. Using the phenomenon of fluorescence as a new form of perception, the specific role of light can be observed very clearly.

Fluorescence

Module 2

Sensorial perceptions: How to make a pigment

Background/Aim

The pupils will learn how to prepare alizarin brine, hear about historical aspects of colouring and learn about plants in their environment. They will learn how to prepare a chemical experiment.

Materials

Madder roots, hydrochloric acid, Bunsen burner, water, alum, soda, Buchner funnel

Krapp plant

Roots of Krapp plant

Follow these steps

Alizarin mainly occurs in the fleshy roots as its glycoside, ruberythric acid; hence, it is necessary to hydrolyse this acid and cleave off the disaccharide group. Pieces of rinsed roots are soaked in a 1% w/w hydrochloric acid solution for 48 hours at room temperature to trigger hydrolysis and the removal of flavonoids that would dull the pigment. Roots are dried and treated with an alum solution (12% w/w): alizarin is extracted and forms a complex. We obtain the pigment adding a soda solution (5% w/w): aluminium hydroxide precipitates and adsorbs alizarin. The pigment is strained in a Buchner funnel and then rinsed and dried.

Results

The pigment as the final product.

Minced roots in solution

Pigment

The Sun and I: *The rainbow – dangers of sunbathing*

Background/Aim

The pupils will learn:

- that sunlight consists of different colours,
- that the sunlight contains invisible light called UV,
- that UV light causes bronzing of the skin,
- that UV light may cause skin cancer,
- how to protect themselves from dangerous UV rays.

The pupils must be able to:

- observe and describe the rainbow and find out under which conditions it appears,
- formulate a hypothesis about its origin,
- devise and realise experiments to verify their hypothesis,
- write a report about their work.

Materials

- Picture of a rainbow
- Pressure sprayer or garden hose, water and white light source
- Transparent bodies: prisms, spheres, glass with water, spherical flask filled with water, etc.
- Each pupil receives a light source (with power supply) and a slit (or a torch; they can make their own slit).

Rainbow

Spectrum

Follow these steps

Ask the pupils to paint a rainbow. Ask them to be careful about the colours. Then show the picture of a real rainbow and ask them to create a rainbow. Let the water emerge from the pressure sprayer or the garden hose and light it up with a source of white light (it works best with sunlight). Try to find the conditions under which a rainbow can be observed. In particular, the pupils should find out that the rainbow only appears when the observer takes a certain position.

These experiments are followed by experiments carried out by either the teacher or the pupils, generating a spectrum through a prism. No detailed description is required as everybody is familiar with this setup. It is necessary to show in experiments that light changes its direction when passing through different media. The borders of the emerging bundle are coloured. If possible, let the pupils experiment by themselves, although their spectrum might not be as colourful as in the teacher's experiment.

Sun protection

Melanoma (Approved release by ESSEX under melanom.de)

Materials

- Pictures of sunbathing
- Experimental equipment to produce an ultraviolet spectrum with a light source (containing UV rays) with power supply, slit, quartz-glass prism, ZnS-screen, quartz-lens and sunscreen

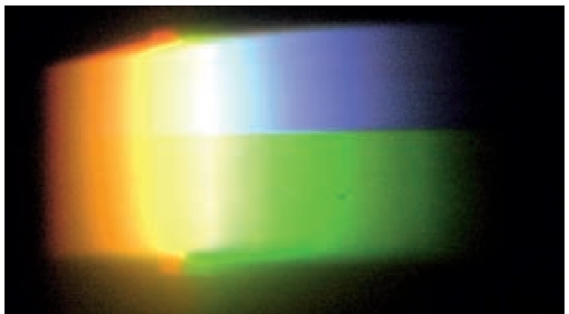
Follow these steps

- Discuss the pictures. Try to answer the questions: What leads to a tanned skin? Do you tan behind a window? Let pupils prepare an experiment that shows that sunscreen can absorb UV light.
- Show the absorbent function of sunscreen in a teacher's experiment.
- Let the pupils identify their skin types by doing Internet researches or a skin type test.

Results

It is not the visible light of the sun that creates a tan, but the UV rays. These rays can cause skin cancer. Be careful and protect yourself.

Absorbing function of suntan lotion



The role of the experiment in teaching science

CONTACT FOR THIS WORKSHOP
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This article gives a short overview of the role of the experiment in teaching science and attempts to deliver a guideline for laboratory work with experiments at the introductory level. It should raise teachers' awareness for the importance of experimental work concerning the right experiment at the right time with the right class. As this task can obviously not be achieved within a short textbook article, we understand our work and this presentation as a starting point for further activities. Especially during the process of working together with teachers from other European countries, the important outreach of this initiative became obvious.

Following introduction and motivation, the task and the importance of the experiment in science are discussed. Didactic arguments for the use of experiments in science lessons and arising methodical difficulties are extracted afterwards. The function of the experiment in the learning process is addressed and specific hints are given about how to prepare, set up, carry out and analyse experiments. Our final conclusion focuses on useful criteria for the evaluation of an experiment. These criteria might help to find experiments that could be used to motivate learners and to introduce the subject at the level of entry – thus encouraging the pupils' interest and enthusiasm for science.

Introduction and Motivation

There is no doubt about the essential stimulus of experiments in teaching and understanding science. A variety of articles and information dealing with this topic can be found in literature. Nevertheless, specific

research and analysis shows that an experimental approach during school lessons sometimes contributes very little to the specific learning process of the students. One reason for this might be that students often do not understand the teacher's intention when he/she decides to use a particular experiment at a given educational level. The teacher should be aware of this problem and prepare and organise the implementation of laboratory work with students very carefully.

In this article, a short overview of these considerations on the role of the experiment is attempted. The article concentrates on first results of this workshop, i.e. the choice and preparation of experiments at introductory level. It tries to provide a guideline for the right choice of experiments at the right level and for the right class. In addition, we refer to available complementary literature on this topic for further reading. Thus, this overview should be seen as a background for further work as presented in the following.

The importance of the experiment in science

The experiment in science is performed to verify or not to verify a hypothesis or prediction in connection with theory. Taking a scientific approach, an experiment represents a dedicated arrangement of devices, which permits to observe processes under reproducible and controlled variable conditions. The experiment can be reproduced at any time and in every place, illustrating the contents of scientific laws and rules. The experimental arrangement quite often also serves to isolate a natural process from disturbing influences which prevent observation or analysis.

Experimental science in general is an inductive science, i.e., if a multitude of experiments leads to the same statement, one concludes the general validity. In this process, experiments often produce further hypotheses and thus drive the development and growth of scientific knowledge and understanding.

Proper distinction between an experiment and an observation must be made, where the latter cannot be identically reproduced everywhere and at any time. One example of an observation is the *rainbow*. An example of a related experiment would be *spectrum analysis*.

What do pupils learn from experiments in science lessons?

There are numerous answers to this question, focussing on different aspects: The first and quite general aspect that comes to mind is to explain the scientific approach itself. Analysing the process of "experimenting" in more detail leads to a long list of answers. One can be entitled "handy skills". Pupils develop and practise their manual skills in concentrated and precise work and when using unknown and sensitive experimental devices, which they even might have to set up or assemble according to given instructions. Beforehand, the experiment has to be planned and pupils have to learn to organise their work, discuss its outline and consider the necessary effort of working time and material. They develop strategies for experimental work and understand how a certain, well-chosen experiment delivers a certain knowledge. For complex processes, this includes the analysis of the process and its separation into a number of simple partial events. Finally, pupils learn to outline experiments, describe them, to take data and to keep records. They have to compile individual data sets and discuss possible faults and errors in the achieved results. Automatically, students will recognise the advantages – and also the problems – of teamwork during planning, execution and evaluation of an experiment. As a general observation, these aspects of experiments positively influence the pupils' learning process and their success. They distinctly serve as a motivation factor.

Methodical difficulties of the experiment in science lessons

Each experiment represents an abstraction of reality, often called "laboratory science". The teacher has to introduce and illustrate this special environment and the related facts in a way that will be accepted by the pupils and enables them to keep it in mind.

Especially for younger students, this might cause a problem, which should not be underestimated. Sometimes qualitative experiments or simplified experiment arrangements, which are immediately hands-on, offer a much closer reference to reality and are preferable to high-tech approaches. The individual choice is certainly dependent on the class and the situation and requires a high level of insight from the teacher.

An enormous amount of time is required, especially for hands-on experiments. This factor is often underestimated. Yet it is not necessary to carry out experiments in every science lesson or to exclusively choose this inductive approach, a combination with more traditional teaching techniques might even intensify their usefulness.

What kinds of experiments can help to learn science?

In all natural sciences, experiments in general serve as an elaborate and tested way to gain knowledge. This does not only apply to demonstration and education, but even more specifically to the general fields of research and development. This extremely wide spectrum makes it necessary to distinguish between widely differing levels of experiments used in the teaching situation.

- ➔ An *"experiment at entry level"* to introduce a subject of the lesson, primarily intends to fascinate pupils, to direct and focus them on a problem. Those experiments can be chosen to surprise students, fill them with enthusiasm like a spectacle or demonstrate or elucidate a more or less well-known natural phenomenon.
- ➔ *"Experiments at the level of acquirement"* should provide the possibility to make new discoveries. They might be set up to measure basic quantities, to confirm a law or to test its range of validity. It is especially instructive if the verification or falsification of a hypothesis can be proven by the pupils themselves.
- ➔ *"Experiments at the level of reinforcement"* can be suitable for a better understanding of the technique in everyday life. They are important for a repetition of the new discoveries and they might be surprising in terms of their results, apparently contradicting previous discoveries and experience, and thus demanding an explanation.

How to prepare and carry out experiments

Experiments should be planned based on a particular problem or question. Students should participate as much at the preparation stage as during the subsequent execution and evaluation phase. They can act as assistants to the teacher, or, in special cases, an individual student or a group of students may independently plan, carry out and present an experiment. Only if a lot of time is required for preparation, setup and adjustment, the experiment should be prepared before the lesson starts.

Usage of modern equipment with black-box qualities implies a detailed explanation of the setup and might even be counterproductive. Thus, the experiments and their implementation should be selected with great care.

One major aspect is that the experiment should serve as a means to gain new knowledge. For this purpose, the most simple and convincing experiment ought to be chosen. On the other hand, it is also desirable to achieve an impressive effect, which helps to emphasise the desired and expected result. In any case, the teacher has to ensure that the students have a clear idea and expectation of what exactly they should observe in a particular experiment. In some cases, it might be useful if the teacher leaves his initial experimental intentions behind and eventually improvises together with the students, following the direction of their work.

Criteria to evaluate experiments

It is obvious that the teacher who implements experimental activities and collaborates with his students in an experiment has the greatest influence on the effectiveness of the learning process. He/She knows his/her students best and can judge their scientific background and limitations in understanding. Thus, he/she can adapt the choice, the level and the quantity of experimental activities. Nevertheless, we summarised some general criteria that exist to evaluate an experiment: whether it stimulates the pupils' interest and enthusiasm towards natural sciences, whether it does not affect them, or even puts them off.

Experiments leading to positive stimulation and motivation towards natural sciences and research should ideally meet the following criteria. Obviously not all those criteria can apply at the same time.

- be simple and clear;
- be easy to repeat, yielding reasonably identical results;
- avoid the use of sophisticated equipment;
- be fascinating, surprising or provocative;
- clearly address or demonstrate the chosen problem;
- have a connection to the daily world of the students and are well adapted to their age group;
- motivate the students to reflect about the problem, open their minds towards the importance of science;
- generate a stimulus to investigate and understand nature;
- respect the students interests and their gender;
- involve counterintuition, surprise or dramatic skills, if applicable;

In the following chapters, we will present a number of physics experiments on Archimedes' Principle and the Lorentz Force. In our opinion, these experiments represent several of the above criteria and have therefore been selected. Nevertheless, they are just a somewhat arbitrary selection from a huge variety of examples suggested by teachers and others, either working in the field of didactics of natural sciences or with a certain involvement in the field. This group of people comes from different European countries. If you have any questions about the experiments, please contact the coordinators.

Descriptions of further experiments are under preparation for publication, for example on the Science on Stage, Germany e.V. website www.science-on-stage.de.

Quotes

"We have to learn again that science without contact with experiments is an enterprise which is likely to go completely astray into imaginary conjecture" Hannes Alfven

"Today's scientists have substituted mathematics for experiments, and they wander off through equation after equation, and eventually build a structure which has no relation to reality"
Nicola Tesla

"The pedagogical value of an experiment is often inverse to the complexity of the experimental device"
James Clerk Maxwell

Literature

- C. Hart, et al., *What is the Purpose of this Experiment? Or Can Students Learn Something from Doing Experiments?*, J. Res. Sci. Teach. 37(7), 655, 2000
- E.Etkina, et al., *Role of Experiments in Physics Instruction – A Process Approach*, The Physics Teacher 40, 351, 2002
- W.M. Roth, et al., *Why may students fail to learn from demonstration? A social practice perspective on learning in physics*, J. Res. Sci. Teach. 34 (5), 509, 1997
- A. Hofstein, et al., *The Role of the Laboratory in Science Teaching: Neglected Aspects of Research*, Rev of Edu. Res. 52(2), 201, 1982

Coca-Cola or Coca-Cola light?

- **Physical topic**
  Archimedes' principle
- **Level in the learning process**
  introduction or reinforcement
- **Age group**
  9–99 years
- **Short description**
  Two identical plastic bottles with a capacity of 2 litres each are filled with Coca-Cola or Coca-Cola light. The labels have been removed. In order to identify which of the two bottles contains Coca-Cola light, both bottles are placed in a larger container (e. g. an aquarium), which is then filled with water. Shortly before the water level reaches the screw caps, the bottle with Coca-Cola light starts to float, whereas the Coca-Cola bottle remains at the bottom of the container.

The bottle with Coca-Cola light floats

List of materials

- Two 2-litre plastic bottles without labels, one of them containing Coca-Cola and the other Coca-Cola light
- Transparent container (e. g. aquarium)
- Water

Description of the setup

The two closed bottles – each containing the same amount of liquid and looking exactly the same – are placed in a transparent container that is slightly higher than the bottles. The container is slowly filled with water. The pupils expect that the Coca-Cola light bottle will soon lift from the bottom and will start floating.

Result: The outcome of the experiment remains extremely exciting right up to the end, as one of the bottles (the Coca-Cola light bottle) only starts floating as the water level reaches the two screw caps. Meanwhile, the other bottle (the Coca-Cola bottle) remains at the bottom (see photo).

Description of the realisation

One way of presenting the experiment would be to incorporate it in a very plausible story:

Storyline

"Julia landed on an island as a castaway, together with a number of boxes full of large plastic bottles containing a brown liquid. The bottles had no labels describing their content – they had been dissolved by the sea. So far, Julia had been unable to find a freshwater well on the island in order to quench her enormous thirst. She therefore opened one of the bottles and carefully sampled the liquid – only to find that the content clearly tasted of sweet Coca-Cola. That should have made Julia very happy. However, she frowned, as she had to remind herself that she was suffering from an illness called "diabetes". For that reason, she was not allowed any sugar. If some of the bottles were filled with Coca-Cola light, though, she would be able to drink those without

any concerns. The question is – how could she find out which of the bottles contained sugar and which of them contained the sweetener that was safe for her?

As Julia had been interested in natural sciences and physics in particular when she was still at school, she had an idea. She carried out an experiment with the bottles and actually found a way of distinguishing the Coca-Cola light bottles from the Coca-Cola bottles. As it turned out later, there was no drinking water on the entire island, but Julia was able to survive thanks to the Coca-Cola light bottles until she was rescued."

Introduction to the experiment

This story can motivate the pupils to develop their own ideas. As most learners in the lower grades do yet not have the physical knowledge to find the right solution, it would be necessary to give them a few hints.

One way would be to remind them that Coca-Cola with sweeteners is advertised as a "light" drink by the producers – hence the bottles with Coca-Cola light should be lighter than the Coca-Cola bottles. At this point, it may be suggested to test whether a bottle of Coca-Cola light floats in water whereas a bottle filled with Coca-Cola sinks. Julia would have had no difficulty to carry out this experiment, as a lot of water (sea water) was surrounding the island.

"We do not know which experiment Julia used in reality. But wait a minute! As you may know already, physical experiments always lead to the same result if the same accuracy is applied every time – no matter where and when they are carried out. We are probably able to repeat Julia's experiment and see whether it was successful."

Professional explanation

Coca-Cola and Coca-Cola light are very sweet drinks. Coca-Cola generally contains a large amount of sugar. Due to this high sugar content, Coca-Cola has a higher density than water. The weight of the filled bottle of Coca-Cola is therefore higher than the buoyancy of the water. Thus, the bottle filled with Coca-Cola remains at the bottom of the container.

For Coca-Cola light, sugar is replaced by a significantly smaller amount of sweetener. Therefore, the drink only has a marginally greater density than water.

As bottles are never completely filled, they always contain a certain amount of air. Hence, the buoyancy suffices to cause the bottle containing Coca-Cola light to float in water.

Additional comments

The experiment also works with smaller light-metal cans with Coca-Cola or Coca-Cola light. Depending on the filling, there is so little air left in the cans that the medium density is too great to allow the can with Coca-Cola light to float. In that case, it helps to increase the density of the water by adding salt or sugar. This subjects the cans to an increased buoyancy. However, it is important that not too much salt or sugar is added, as both cans would start floating!

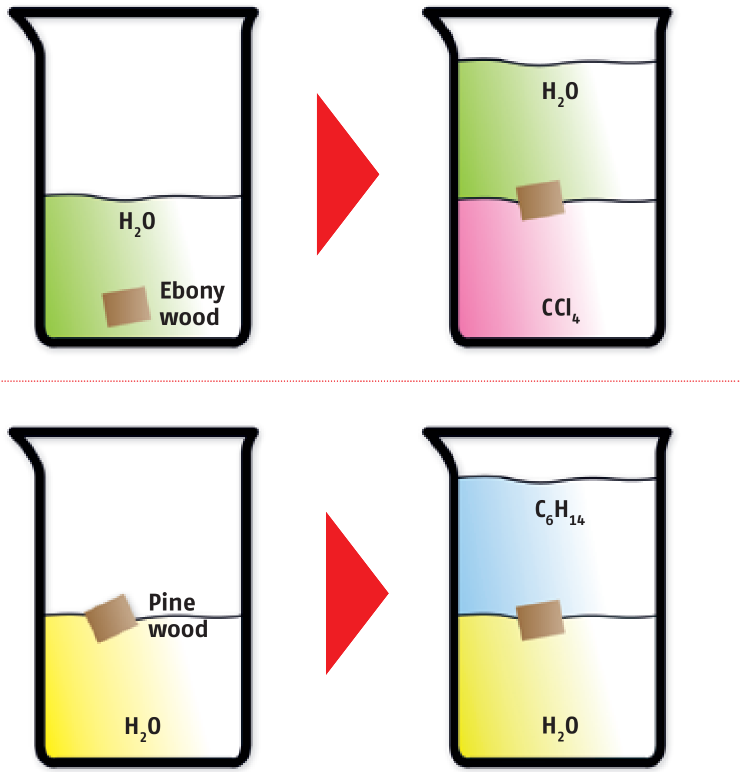
Bibliography

Berry, D.A.: *A potpourri of physics teaching ideas, selected reprints from The Physics Teacher April 1963 to December 1986*, American Association of Physics Teachers, College Park, MD 20740-4100, U.S.A. o. J. 1987

Meisinger, K.: *Physikalische Experimente mit Dosen*, Schriftliche Zulassungsarbeit zur Ersten Staatsprüfung für das Lehramt an Hauptschulen, Augsburg 1994

Ebony & Pine

- **Physical topic**
  Archimedes' principle
- **Level in the learning process**
  Introduction
- **Age group**
  15–16 years
- **Short description**
  Due to the density of fluid, one piece of wood sinks or floats, and vice versa.



List of materials

- Two tall 1-litre beakers
- Half a litre of carbon tetrachloride, hexane
- One litre of tap water (half and half)
- Small piece of ebony
- Small piece of pine
- Some green-, orange-, yellow- and blue dye (small quantities)

Description of the experiment

Ebony has a density $d = 1.3$ g/cm^3 – hence it sinks in water, but floats in carbon tetrachloride (CCl_4), which has a density $d = 1.6$ g/cm^3. The qualitative experiment is as follows: We pour water into one of the tall beakers with a capacity of 1 litre, until it is half-full. Afterwards, we add a piece of ebony. This piece of wood sinks. Subsequently, we add carbon tetrachloride to the beaker until it is completely full. Both liquids do not mix (with each other). We can see that the piece of ebony remains within the interface of H_2O/CCl_4. As the two liquids are clear and colourless, we can make the experiment more impressive by colouring the water with just one drop of green food colourant to leave it clear but not colourless, and by colouring carbon tetrachloride with just one drop of methyl orange.

The pine-wood has a density $d = 0.9$ g/cm^3, so it floats in the water, but sinks in hexane, which has a density $d = 0.7$ g/cm^3. The phenomenological and qualitative experiment is: We pour water into one tall beaker with a capacity of 1 litre until it is half filled and then add one piece of pine wood. This piece of wood floats. Afterwards, we pour in hexane until the beaker is full. Both liquids do not mix with each other. We can observe that the piece of pine wood also remains in the interface between water and hexane. Like in the first experiment, we might consider achieving an enhanced effect with dyes – with just one drop of yellow food colourant and one drop of ethylene blue for the hexane.

Comments

Any material either floats or sinks; we just have to identify the suitable fluid.

Hazards

Hexane and carbon tetrachloride are toxic substances. Observe health- and safety regulations.

Levitating a ship in a gas

→ **Physical topic**
Archimedes' principle

→ **Level in the learning process**
introduction or reinforcement

→ **Age group**
13–14 years

→ **Short description**
A light ship is levitating in the gas sulphur hexafluoride (SF_6). This gas has a density that is about 5 times higher than the density of air. Therefore, the buoyancy force is great enough to compensate for the weight of the lightweight ship.

The levitating ship

List of materials

- big aquarium or vessel
- blue-coloured water
- some small toy ducks
- bottle of SF_6-gas
- valve to diminish the pressure
- hose to transport the gas into the vessel
- gauge to control the gas flow
- light ship

Description of the setup

Ship

A floating ship (as shown in the picture) on the one hand has to be light, but on the other hand also needs a minimum volume to produce a sufficient lifting force.

For the ship's construction, the ribs can be cut out of thin plates of polystyrene, while the ship's body can be constructed with glue. Finally, the body's skin can be realised using ordinary rescue foil.

Gas filling

The gas sulphur hexafluoride is invisible and not poisonous. However, breathing it in might cause problems of suffocation. For this reason, the gas container made of glass or acrylic should be closed by a cover. The cover has to have a hole for the transportation tube. With a pressure reducer and an additional measuring instrument for the gas flow, the gas flow has to be regulated to prevent the air in the container and the gas from mixing. The air has to be pressed to the top. For this reason, the gas should be filled into the container as closely to the bottom as possible. Finally, a certain amount of time is required to fill the container with a specific, previously established gas flow. Toy ducks floating in the blue-coloured water can be used to visualise the realisation of Archimedes' principle in a liquid.

Description of the realisation

In order to achieve special fascinating effects, the teacher could state that he/she has a special ability to overcome gravitation and plans to build a very big ship with which he/she may float to every place on earth. As proof, a small model has already been built and successfully been tested.

Just 15 to 30 minutes before the experiment is shown, the container has to be filled with gas in an adjacent room and has to be covered with a big sheet. The ship is also covered. Finally, the container is uncovered and the pupils realise that there are swimming toy ducks on the blue-coloured water. Before the uncovering of the ship, the teacher can raise attention and excitement even further by mentioning that this phenomenon has so far only been observed by very few people. With great care, the cover of the container is lifted and the ship is introduced into it very slowly. With swinging movements, the ship floats just above the ducks.

Finally, the students should learn that physicists did not overcome gravitation, but that well-known physical laws (Archimedes' principle) are responsible for this phenomenon.

Professional explanation

Archimedes' principle says that the lifting force of a body surrounded by gas is equal to the gravitational force of the gas displaced by the body. If the ship filled with air is surrounded by air, it will not float because the buoyancy (lifting force) is smaller than its weight. The air displaced by the ship is lighter than the ship itself, because the ship is built of material with a higher density than air. In contrast, at the same temperature, sulphur hexafluoride (SF_6) has a density that is five times higher than the density of air. If the ship is big enough, the SF_6-gas displaced by the ship is heavier than the ship itself. The ship will sink into the SF_6-gas until an equilibrium between lifting force and gravitational force is given. The ship will be floating on the gas.

Additional comments

- It is impressive for the spectator if the ship starts to swing when tapped with the fingers.
- If there is not enough gas in the container, the ship will be floating inside of the container. However, there is a risk that the gas might

diffuse into the ship over its rail, which will finally cause the ship to sink.

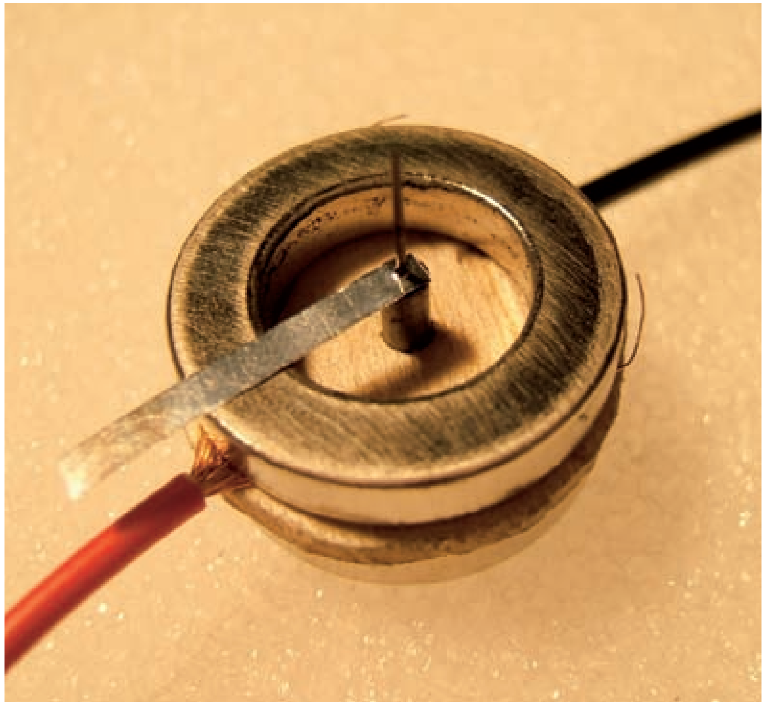
- The gas sulphur hexafluoride is quite expensive. A 10-litre bottle costs about 400 Euro. However, you can fill many containers with one bottle. Thus, it might be a good idea to share a bottle with several schools and just pay a share for participating in one bottle.
- The ship should be constructed with very light material. Otherwise, it becomes quite big, which also influences the possible size of the container. Certainly with regard to the costs for the gas, the ship should be small.
- A similar experiment: soap bubbles are floating in CO_2-gas.

Bibliography

www.physikanten.de

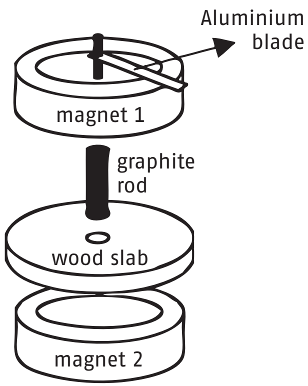
Rotating blade (homopolar motor)

- **Physical topic**
  Lorentz force
- **Level in the learning process**
  introduction or reinforcement
- **Age group**
  16–19 years
- **Short description**
  An electric current along a metallic thin blade immersed in a normally oriented magnetic field causes fast blade rotation due to the Lorentz force.



List of materials

- Two ring-shaped NdFeB (NIB) magnets, axially magnetised (26.75/16 x 5mm. r-27-16-05-N, www.supermagnete.de).
- One circular balsa wood slab (~5mm, slightly wider than the magnets).
- Two graphite rods, one of them with a central hole fitting the other (the thinner one can be a 0.5 mm graphite bar from a pencil).
- Aluminium foil for the blade.
- Multifilar electrical wire.
- DC power supply transformer (3–12V) or 9V battery (less durable).



Description of the setup

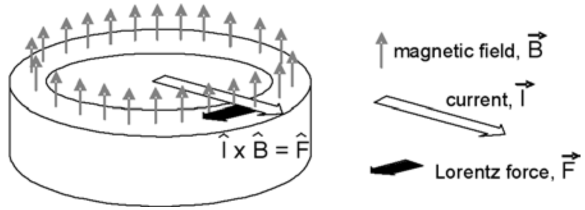
The balsa wood slab is cut circularly, slightly exceeding the size of the magnets. A central hole is then drilled to accommodate the thicker graphite rod that fits tightly into it, leaving its top hole open. The wood slab is then 'sandwiched' between the magnets that experience a strong mutual attraction (this effect is used to connect one of the electrical wires to the top magnet). The other wire is connected to the central graphite rod, underneath the balsa separator. Subsequently, the thinner graphite bar is inserted into the hole of the thicker rod, assuring electrical contact. At one end of the aluminium blade (see picture for cut), a small hole is drilled, enabling it to rotate freely around the graphite bar.

Description of the realisation

The setup described above is placed on a non-magnetic horizontal base. The electrical wires are then connected to the DC power supply or 9V battery. To start the rotation, gently touch the blade. The blade will rotate fast as tiny sparks are produced in close proximity to the contacts.

Professional explanation

Since the aluminium foil is subjected to DC voltage at its ends, an electrical current flows along this foil. Regardless of the blade position, this radial current is perpendicular to the magnetic flow near the magnet, giving rise to a force that causes the blade to rotate. As long as there is a radial current, the force will create its impact. The simplicity of the setup is almost self-explanatory.



Additional comments

- At least one of the magnets must be coated with metal; otherwise no current would flow. The magnets in the experiment have been supplied with a Ni coating.
- If the aluminium foil is too thin, fold it once or twice to shape the blade before drilling the hole.
- The top magnet surface has to be clean and smooth, minimising friction and optimising electrical contact. If the surface becomes rougher after some runs, use smooth sandpaper to clean the magnet surface and then remove the remaining fine particles with adhesive tape.
- The DC power supply from a transformer is more suitable than the battery to control the device.

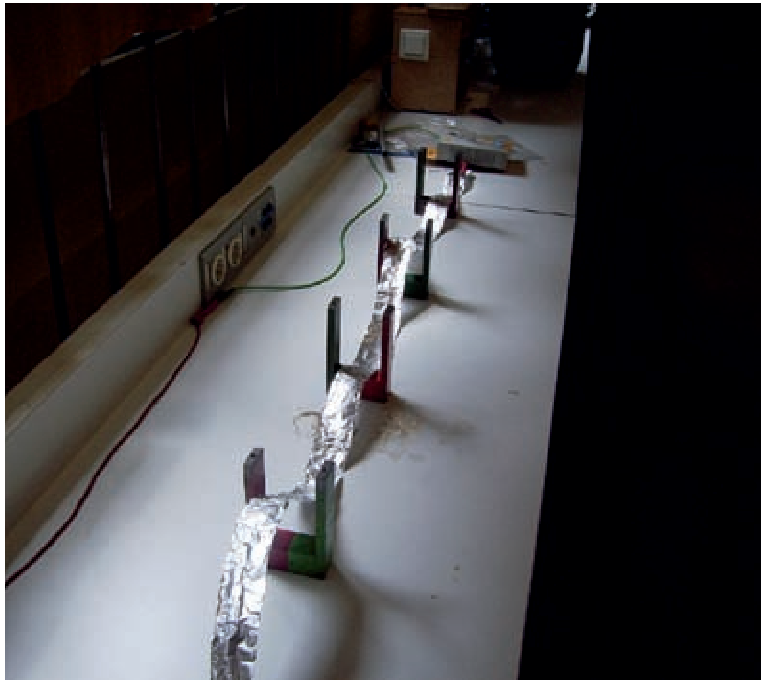
Undulating aluminum strip

→ **Physical topic**
Lorentz force

→ **Level in the learning process**
introduction or reinforcement

→ **Age group**
16–19 years

→ **Short description**
A Lorentz force changing direction and strength causes an undulating motion in a flexible aluminium strip.



List of materials

- At least four horseshoe magnets
- Flexible aluminium strip, length: 2 m, width: 3 to 4 cm
- 2 clamps for current
- Alternating current with variable frequency (up to 3A)
- 2 power cables
- Foot switch
- Gold-coloured foil to cover the horseshoe magnets
- Sheets to cover cables and clamps

Description of the setup

Four or even more horseshoe magnets are put on a table in one line at a distance of 30 to 50 cm, alternating their polarity. The aluminium strip is positioned between the poles (see figure). At both ends of the strip, clamps for the current are fixed and connected to an alternating current generator with variable frequency.

Description of the realisation

The undulating aluminium strip has the potential to be a very motivating experiment to introduce the Lorentz force if set up in the following way: The horseshoe magnets should be covered – for example with gold foil. Clamps for current and cables should also be invisible and could be hidden with a cloth. If the frequency generator can be operated by a foot switch, it should be positioned under the table, without being visible for the students. For a first experiment, the frequency of the alternating current should be chosen at around 1 Hz. This results in a smoothly and mysteriously undulating aluminium strip.

The experiment is very clear and simple and can be repeated several times, always showing the same results. It is surprising, fascinating and thus motivating students to think about the reason behind their observation of the moving strip.

Professional explanation

An electric conductor, in this case the aluminium strip, perpendicular to a magnetic field which is caused by the horseshoe magnets, feels a force perpendicular to the current and the direction of the magnetic field – called Lorentz force. Depending on the polarity of the horseshoe magnets, the aluminium strip is lifted or pressed down. With a direct current, several hills (depending on how many horseshoe magnets are used) can be observed. In the case of an alternating current, the Lorentz force impacting on the aluminium strip changes in direction and strength, which results in a slowly varying wave.

Additional comments

- The distance of the horseshoe magnets influences the shape of the observed wave.
- The aluminium strip should not be folded.
- The current should be chosen in a way that prevents the aluminium strip from being lifted above the horseshoe magnets and from finally falling down to one side.
- The horseshoe magnets should have the same magnetic field strength.

A special role of the experiment in teaching physics –

"The Experiment of the Week"

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Can you imagine students who run up the stairs of the schoolhouse in order to be the first to occupy a front seat in the physics room? For more than two years we, the subject heads for physics and trainees at the Hardenberg-Gymnasium, have been able to observe this phenomenon every week during one of the lesson breaks.

This contribution describes the project "The Experiment of the Week", which makes it possible to observe surprising and exciting physical phenomena suitable for creating associations with familiar situations in everyday life – for a better understanding of these phenomena. Information about the requirements and the restrictions concerning the realisation of the project is presented in order to inspire teachers at other schools to initiate similar projects.

What is the project about and why was it initiated?

Physics is everywhere – but only a few students enjoy physics in the classroom. Physics as a school subject does not seem to be able to live up to educational demands. Many of the concepts to be learnt are too complicated; all in all, there is not enough time to learn, to think in terms of physics, to understand fully and in the end to practise what has been learnt. The student groups are too large; there are no or not enough practical exercises, and many physics teachers are too maths-oriented in their lessons – and hence do not dare to work with demonstration experiments or – even more demanding – with hands-on activities. These basic conditions have led to a situation where a lot of students primarily learn physical formulae and technical terms without being able to relate them to their surrounding reality. In many cases, physics as a school subject has lost much of its inherent proximity to nature and the environment. To many students, physics seems to be remote and unreal like an extinct and difficult foreign language. Therefore, they cannot see any sense or use in studying it [1].

About 12 years ago, we therefore started to establish experimental stations along the corridor in front of the physics lecture rooms at the Hardenberg-Gymnasium. The idea was that students should get the opportunity to experience a number of physical phenomena playfully, using their own initiative and without being supervised [1]. Up to now, 27 experimental stations have been established permanently along the corridor. Unfortunately, no more space is available for further stations now. Some other interesting physics experiments have not been set up for operation by unsupervised students because of their inherent risks.

To overcome these limitations, we have developed the project "*Experiment of the Week*". A particularly attractive, regular weekly event aims to expose the students to certain phenomena in physics – some new and unknown to them so far. In addition, they are particularly suitable for making connections with familiar situations in everyday life – thus contributing to a better understanding and establishing a feeling for the general influence of physics on everything and everyone. Furthermore, spectacular physics attractions can be demonstrated in an entertaining, unexpected or surprising way, enabling the students to have fun with natural sciences. This positive approach inspires them in a much more sustainable way to memorise and reflect on their observations with intellectual pleasure and curiosity than ordinary lectures.

An experiment concerning heat conduction

Physics is everywhere and can be surprising and even thrilling.

Where and when do the presentations take place?

Since the beginning of November 2002, the "*Experiment of the Week*" show has taken place in a physics classroom every Tuesday during the first break. Posters in the school building announce the topics of the experiments. As a rule, the experiments start five minutes after the beginning of the break, which enables all interested students to take part, especially those who come from more remote classrooms. The event finishes after a few minutes – well before the end of the break – to permit the students to return to their classrooms in time.

Who is watching the experiments?

The event is primarily targeted at all interested students of the Hardenberg-Gymnasium. For the very first shows, we still invited students on the way to the schoolyard to participate. Meanwhile, a group of regular participants has formed, some of them even running to the physics classroom to occupy the desired seats in the front row. When the announced experiments are of particular interest, the room is overcrowded and the door remains open, in order to give students in the corridor the possibility to watch the experiment at least from a distance.

Spellbound spectators

Participation is widely spread and basically every age group participates: Pupils from grades 5 to 13 (also including those – often very young "fans", who do *not* have physics courses yet), young teachers during their teacher training phase (also including those who do *not* teach physics), and last but not least, members of the "older generation" of teachers (especially including some teachers who have *not* shown any particular interest in our subject up to now).

Who presents the experiments?

The experiments are prepared and presented by young teachers in their teacher training period. Naturally, it is not possible to present experiments that require a lot of preparation time, a wide range of equipment or sophisticated technologies such as computers, lasers or meters. Most of the experiments have been chosen because of their effective and spectacular results, though it has not necessarily been our intention to compete with popular TV shows or computer animations.
Because of the short time available – only a few minutes – only an elementary explanation of the individual phenomena is possible. The "hard" physical background cannot be addressed as a topic. However, that is precisely one of the complications of a good presentation, which requires reflection, skill and creativity.

Which experiments have been presented?

A small selection of the subjects we have addressed so far:

- ➔ How to distinguish Coke from Diet Coke?
- ➔ How to uncork a wine bottle without destroying the bottle, if you do not have a corkscrew?
- ➔ How to empty a full water bottle as quickly as possible?
- ➔ Why do raisins "dance" in a glass of sparkling water?
- ➔ Are there paper clips that take their original shape again after having been twisted?
- ➔ How to produce an elastic bounce ball with modelling clay?
- ➔ How to saw a piece of chalk with a sheet of paper?
- ➔ How to blow out a candle flame from a distance of 5 m?
- ➔ How to create sparks and lightning?
- ➔ Which are the special qualities of liquefied air? What can you do with it?
- ➔ How to break a wooden stick wrapped firmly with paper loops without breaking those paper loops?
- ➔ Physics experiments in the kitchen.
- ➔ Alternative uses of balloons.
- ➔ How can you levitate a ship using gas?

Most of the experiments originate from two books with the title "Physikalische Freihandversuche". The collection was recently published by the publishing house Aulis [2].

Why do it?

Just look at the pictures – our classroom is crowded during the breaks! The students are enthusiastic about the shows; they always request further information about the demonstrated effects and very frequently ask us to continue with the project in the future.

The following development is conceivable:

- ➔ Chemical and biological experiments should be included.
- ➔ Students could plan and prepare their own experiments and demonstrate them independently or with some support by teachers.

- Experiments are shown in other places within the school building or even in the schoolyard.
- Distribution of explanatory handouts is planned.

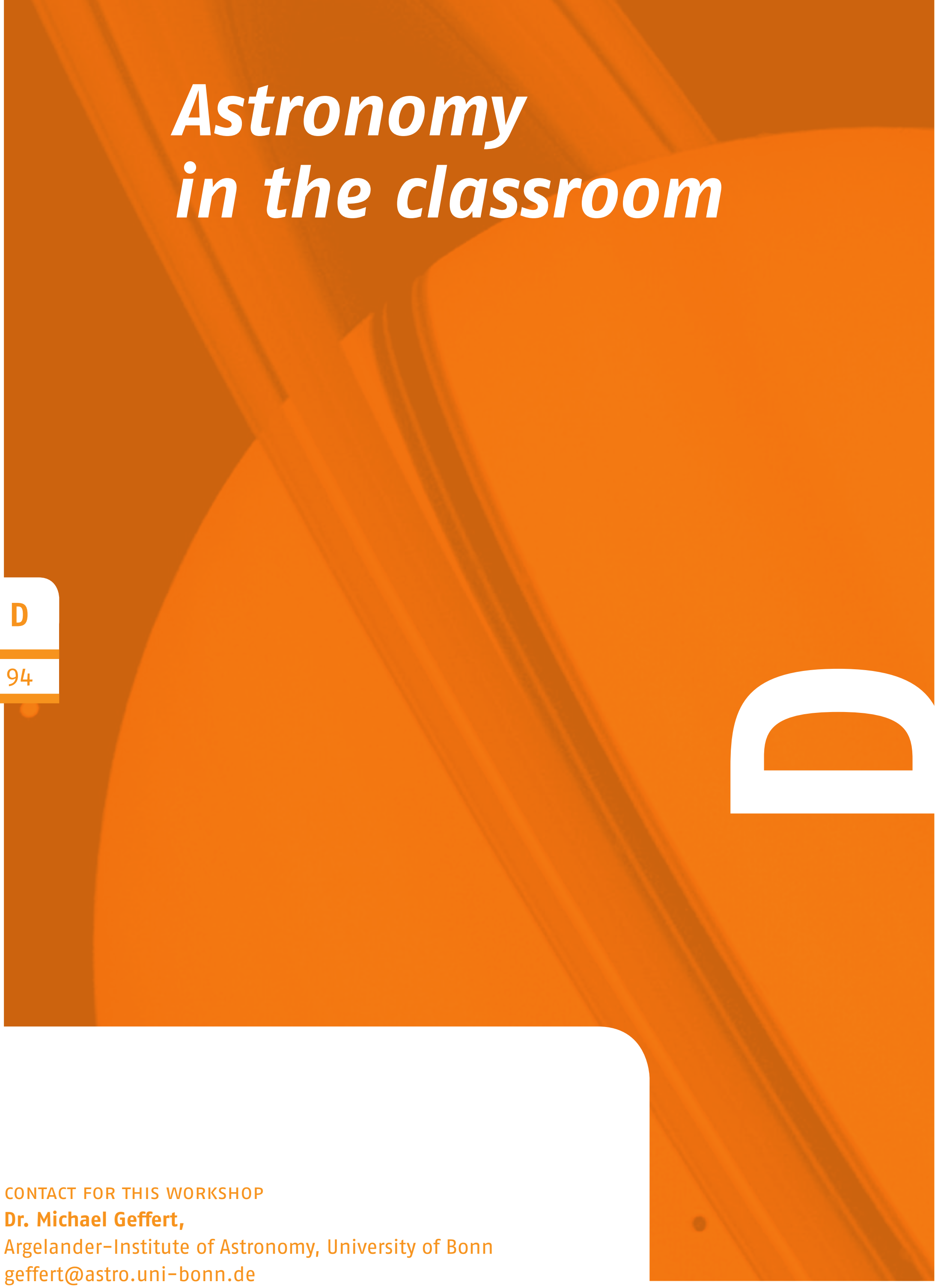
From our experience, we conclude that our project "Experiment of the Week" serves as an ideal way to make physics more appealing and interesting for students [3]. Even more importantly, it opens their minds towards the fun and beauty of natural sciences (in addition to their relevance) and perhaps even might lead to "some of them starting to enjoy physics" .

Literature

[1] Miericke, J.: *Physik zum Anfassen*. In: PhyDid 1/2 (2003) p. 30–38

[2] *Physikalische Freihandexperimente*. 2 Bände, incl. CD, Aulis-Verlag Deubner, Köln, 2004

[3] Miericke, J.: *Physik in der Pause – Erfahrungen mit dem Versuch der Woche*. In: Unterricht Physik 17 (2006), Nr. 93, p. 46–48



Astronomy in the classroom

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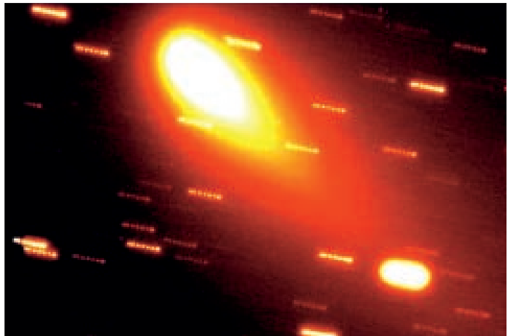
Although astronomy is generally not a separate subject in schools, many teachers have experienced that pupils are often fascinated by topics related to astronomy and the universe. One reason for this particular interest in the subject is that the pupils can observe astronomical events such as eclipses, comets and meteor streams themselves.

Moreover, even "normal" everyday phenomena such as the appearance of planets, the path of the Sun in the sky or the phases of the Moon, are of great interest for the learners who are instructed to observe the sky. Observations coupled with explanations can guide children towards a better understanding of nature and can also make them more receptive for natural science in general.

Why astronomy is fascinating

Looking back over the last 15 years, the increasing interest in astronomy was caused by a "chain" of important astronomical events that people in many countries were able to observe. In 1993 and 1994, the supernovae in Messier 81 and Messier 51 caught a lot of attention among amateur astronomers who observed them with their telescopes. In 1997, the comet Hale-Bopp was another phenomenon in the sky, visible



Children and adults alike are fascinated by "new" objects in the sky. Comets for example are visible to the naked eye sometimes – in this case Comet 73P/Schwassmann Wachmann 3 (Source: Observatorium Hoher List) to the naked eye for several weeks. In 1998, the Leonids showed an unpredicted maximum and in 1999, thousands of people travelled to places in Europe where they were able to observe the total solar eclipse. These extraordinary opportunities to watch such unusual events have raised the awareness of astronomy in the general public and among school children. After 1999, even a regular eclipse of the Moon unexpectedly led to a higher level of interest within the general public.

A second motivation is based on the results of recent astronomical research and the images of distant galaxies. From these distant objects, even light travelling at the highest speed, needs millions of years to reach the earth. Here the combination of facts and images fascinates people and makes them susceptible to explanations of astronomical observations. School children also feel the need for explanations of astronomical topics. In primary school in particular, the children's interest in astronomy is strongly motivated by newspapers, television and the Internet. They receive a lot of new information and want to understand these new facts.

Children in the age group 6 to 12 are especially motivated by astronomy (Source: Deutsches Museum Bonn)

Astronomy – suitable for a number of school subjects

Astronomy in school can be easily integrated into natural science lessons, teaching subjects such as mathematics, physics, chemistry, geography, etc. Natural science is the aspect of human culture that motivates people to ask questions in order to understand their environment. With a better understanding, it is possible to develop models and solutions for unresolved problems.

Moreover, there are also interactions between astronomy and other sciences. From a general point of view, it is clear that teachers and pupils are individuals acting in a certain environment, which is influenced by aspects of different – not only natural – sciences.

Art and natural science interact at times. One good example for this are the constellations in the sky. Constellations are precious products of the human imagination, although they are not of great importance for modern astronomy. The painting of a newly invented constellation is one example of how astronomy may be used for an interdisciplinary teaching approach.

Interactions between natural science and art have a long tradition. Before 1900, the drawing technique was widely used in natural sciences – from biology to astronomy. Since photography as a visualisation method for astronomical phenomena was only invented at a later stage, drawing techniques were used to document visual observations before 1890. The astronomer E.W. Tempel (1821–1889) was one of the most successful discoverers of comets. His observations benefitted from the fact that he had started his professional life as an artist. Tempel was a gifted painter, his drawings helped astronomers to get a better understanding of the astronomical "nebula". Some of them turned out to be important galaxies. On the other hand, artists have always reacted to new technical developments and particularly to new images from satellites or even microscopes. Artists like S. Francis (1923–1994) have adopted structures of images from biology and medicine in their paintings. Nowadays in primary schools, drawing and painting are used to deepen and repeat several topics presented in the lessons.

Frequently, there is an interesting historical component in natural science experiments, which may be used for didactic purposes. If pupils follow the history of a science, they will get a better and more comprehensive view of the interrelations and interesting questions. The discovery of the first minor planets – from early attempts of astronomers to organise a joint search to the rediscovery of the first asteroid, based on Gauss's calculations – is a nice example of how history might provide an insight into the work of modern scientists. It is the first example of a coordinated project with many participating astronomers and of a productive link between the practical and theoretical work of scientists.

European astronomy

For a topic that is not an independent school subject, an active exchange of suitable experiments and teaching methods is very important. Several observatories and other institutions in different European countries offer astronomical material for schools. Moreover, a European group of astronomers – "The European Association for Astronomy Education (EAAE)" – organises summer schools and has provided educational material for school children.

The aim of the topic astronomy in the context of this book is to give an idea of the possibilities for teachers in European countries, should they wish to incorporate astronomy in different school subjects. During the discussions among the workshop participants about a possible collection of astronomical experiments for teaching purposes, we have developed a schema of topics. The following structure may be used as an overview of astronomical experiments:

Everyday phenomena:
day and night; seasons; phases of the Moon (phenomena); sundials; star trails; rising and setting; constellations; pole star; simple orientations; observation of satellites and meteors; tides (observation)

Sun, Moon, Earth:
eclipses; phases of the Moon (explanation); mutual interactions; tides; path of the Sun (daily and annual); bound rotation of the Moon;

Solar System:
parts of the solar system; Sun; planets; minor planets; comets; meteors; satellites of planets; Kuiper Belt objects; motions in the solar system; mutual interactions; origin of the Sun and the planets;

Stars:
origin of the stars; lifetime of a star; star clusters; constellations; seasons; formation of Zodiac; distance of stars; mythological stories; extrasolar planets

Milky Way, Galaxies:
Milky Way as a star system; Milky Way as a galaxy; different forms of galaxies; star clusters; structure of the Milky Way; dimensions; dark matter

Universe:
space technology; motions from earth to universe; expansion of the universe; Big Bang; problem of infinity; dark matter; future of the universe; life existence in the universe; circumstances for life development in the universe, extrasolar planets; worm holes; matter.

To continue our discussions and to present new experiments to European teachers, we will establish a new website for an exchange of astronomical experiments between teachers of different classes. The website "The astronomical experiment of the month" will present more experiments on the different topics. In the following, we will give three examples of experiments. The authors are from different countries in Europe. From the large number of possibilities, we have chosen experiments which range from simple astronomical observations (experiment 1) to an experiment which demonstrates the location of the Earth, the planets and the stars in the universe in a simple way (experiment 2) and finally to an experiment with a more physical background (experiment 3).

Literature

Hannula I., 2005, PhD-Thesis, University of Helsinki,
"Need and possibilities of astronomy teaching in the Finnish comprehensive school"
http://ethesis.helsinki.fi/julkaisut/mat/fysik/vk/hannula/

Homepage of the EUROPEAN ASSOCIATION FOR ASTRONOMY EDUCATION (EAAE), http://www.eaae-astro.org/

Homepage of the European Southern Observatory (ESO):
http://www.eso.org/

Homepage of the astronomical experiment of the month:
www.astro.uni-bonn.de/~geffert/ASTEM/astem.html

Experiment 1:

Determination of the geographic latitude by measuring star trails

→ **Physical topic**

Relationship between horizontal and equatorial system

→ **Level in the learning process**

Introduction or reinforcement – astronomical coordinate systems

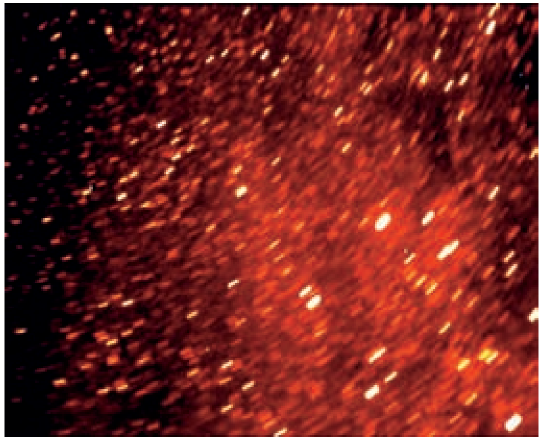
→ **Age group**

14–15 years

→ **Short description**

The geographic latitude of a place on Earth is determined by measuring the rising angle of the stars with regard to the horizon from the selected place

Star trail exposures contain information about the observer's location on Earth, indicating geographic latitude



List of materials

Reflex camera with normal lens (focal length of about 50 mm); tripod; clock with second hand; cable release; red-light lantern; film for slides (1000 to 1600 ASA); materials for classes (pencils; rulers; rubber; protractor; tracing paper)

Description of the setup

The first step is the exposure of the photographs. Photos are taken from a position not contaminated by surrounding lights when the sky is clear. The camera should be oriented according to the cardinal points in the East (or West). The exposure time should be at least 15 minutes. After developing the film, the work can continue in the classroom.

Description of the realisation

Initially, the learners study the relationship between the equatorial and the horizontal coordinate system. The geographic latitude of the place is 90 degree minus the angle between the horizon and the star trails. In order to determine the latitude in the classroom, the pupils have to copy the horizon and the star path on tracing paper. From the angle between the two, the geographic latitude can be calculated.

Professional explanation

Star trails on the photographs appear due to the rotation of the Earth. The axis of the rotation points to the pole star. Therefore, the orientation of the star trails depends on the geographic latitude. (Imagine the star trails at the poles or the equator of the Earth).

Additional comments

In order to obtain good results, it is necessary to adjust the camera in parallel to the horizon. It is also convenient to take several photos and to determine the latitude for each photo independently. The final result is obtained by calculating the average of the individual photos.

Bibliography

Vinuales, E. & Ros, R.M.; 1995; La fotografia una herramienta para hacer Astronomia, MIRA Ed. Zaragoza (Spain)

Experiment 2: Zodiac

- **Physical topic**
  "Living model" of the Zodiac
- **Level in the learning process**
  Modelling and practical work
- **Age group**
  13–19 years
- **Short description**
  Study the locations of the zodiacal constellations around the Sun and the orbit of the Earth

List of materials

Coloured sheets of papers (DIN A3), coloured pencils, bulb, globe, transparencies of the zodiacal constellations and their mythological figures

Description of the setup

Using people as zodiacal constellations, the Sun and the Earth, constructing the Zodiac with people

Description of the realisation

Draw the twelve pictures of the zodiacal constellations in magnified format, using the overhead projector. If you wish, draw the respective mythological figure on every picture. Construct the circle of the Zodiac with people. Two people are in the middle of the circle, illustrating the Sun and the Earth. Discuss the ideas: the order of the constellations in the Zodiac, the revolution of the Earth around the Sun, the connection between the Zodiac and the revolution of the Earth, etc.

Professional explanation

The annual path of the Sun as seen from the Earth seems to move through the constellations following the same circle. This circle is called the ecliptic. As a matter of fact, there are thirteen constellations in the path of the Sun, but usually the thirteenth constellation is ignored when constructing the model of the Zodiac. This model is very educational in terms of perceiving the movements in our solar system.

Additional comments

Including further details in the presentation session highly depends on the level of the learners' knowledge. It is important to discuss the topic of distance of the stars and the origin of the constellations with the students at the beginning.

Bibliography

Ros, Rosa M., 2000., Proceedings of the 4th EAAE International Summer School. Tavira, Portugal

Experiment 3: Spectrum of the Sun with a CD-ROM

→ **Physical topic**

Optics, spectroscopy, Sun

→ **Level in the learning process**

Spectroscopy of Sun and stars. The same method may be used to investigate the spectra of neon lamps, etc.

→ **Age group**

10–19 years

→ **Short description**

A CD-ROM is used to produce a spectrum of the Sun

A CD may be used to obtain spectra, for example of a neon lamp.

List of materials

CD-ROM, dark room, a sheet of paper or cardboard with a slit (about 1 mm by 5 cm)

Description of the setup

A dark room is required, where a small section of a window receives light from the bright sky or from a bright wall (direct sunlight is not required!). Paper – with the slit vertically orientated – must be placed towards the light source. The observer has to stand with the back to the window and holds the CD in front of him/her.

Description of the realisation

The orientation of the CD has to enable the observers to see the white reflected slit. **The slit should appear in the region where the grooves are parallel to the slit!** The CD is then turned around a vertical axis – either to the left or to the right – until a bright rainbow-coloured band appears.

Professional explanation

The setup contains all elements of a simple spectrograph. The grooves in the CD are at a distance of 1.4 micrometres, which is several times the wavelength of visible light. Therefore, the CD may be used as a diffraction grating.

Additional comments

This experiment can be enhanced by building a simple spectroscope, by observing the spectral lines of a neon lamp, etc.

Bibliography

The author of this experiment is Joachim Köppen from the Observatoire de Strasbourg/France. A French, English or German description is available at: http://astro.u-strasbg.fr/~koppen/spectro/spectrod.html

Annex

Overview of activities:
Project events
Participants

Feedback Questionnaire

Overview of activities

Project events

2004

26th–28th November

Inaugural meeting at the Physics Centre of the German Physical Society in Bad Honnef near Bonn (Germany)

2005

9th–11th June

Follow-up meeting within the education conference "EduNetwork 05" at the Landesschule Pforta in Schulpforte near Leipzig (Germany)

November, 21st –25th

Follow-up meeting as part of the Science on Stage Festival 2005 at the European Organization for Nuclear Research (CERN) in Geneva (Switzer-land)

2006

22nd –24th September

Conference "Teaching Science in Europe" at the Science Centre "phaeno" in Wolfsburg (Germany)

2007

2nd–6th April

Upcoming meeting within the Science on Stage Festival 2007 at the European Synchrotron Radiation Facility (ESRF), the Institut Laue-Langevin (ILL) and the European Molecular Biology Laboratory (EMBL) in Grenoble (France)

Participants

Working groups – topics: 1 = Teaching science in primary school, 2 = Interdisciplinary teaching, 3 = The role of the experiment in teaching science, 4 = Astronomy in the classroom.

	NAME	FIRST NAME	COUNTRY	TOPIC	
Mr.	**Beddegenoodts**	Marc	Belgium	2	
Mr.	**Bonnefonds**	Pierre	France	1	
Mr.	**Bräucker**	Richard	Germany	2	Coordinator
Mr.	**Buschhüter**	Klaus	Germany	2	Coordinator
Ms.	**Cerrato**	Guiseppina	Italy	2	
Mr.	**Daman**	Pascal	Luxembourg	2	
Ms.	**De Craemer**	Sonja	Belgium	1	
Ms.	**De Masi**	Ernesta	Italy	2	
Ms.	**Dobkowska**	Maria	Poland	2	
Mr.	**Farusi**	Gianluca	Italy	2	
Mr.	**Fernandes**	Antonio	Portugal	3	
Mr.	**Geffert**	Michael	Germany	4	Coordinator
Mr.	**Gravenberch**	Frits	Netherlands	1	
Ms.	**Hannula**	Irma	Finland	4	
Mr.	**Haupt**	Wolfgang	Austria	2	
Ms.	**Heber**	Irmgard	Germany	1	
Mr.	**Heiderer**	Hans	Austria	3	
Ms.	**Hellemans**	Jacqeline	Belgium	3	
Ms.	**Huemer**	Judith	Austria	4	
Mr.	**Jilek**	Miroslav	Czech Republic	3	
Mr.	**Kettunen**	Juha	Finland	2	
Mr.	**Konstantinou**	Dionisios	Greece	2	
Ms.	**Kucerova**	Radka	Czech Republic	1	
Mr.	**Lusignan**	François	France	1	
Ms.	**Massidda**	Victoria	Italy	2	
Mr.	**Miericke**	Jürgen	Germany	3	Coordinator
Ms.	**Musilek**	Monika	Austria	1	Coordinator
Mr.	**Nieminen**	Harri	Finland	1	
Mr.	**Obdržálek**	Jan	Czech Republic	2	
Ms.	**Palici di Suni**	Cristina	Italy	1	
Mr.	**Papamichalis**	Konstantinos	Greece	3	
Mr.	**Pausenberger**	Rudolf	Germany	1	
Mr.	**Popov**	K. Tsviatko	Bulgaria	1	
Ms.	**Reinholtz**	Christine	Germany	2	
Ms.	**Schmitt**	Annette	Germany	3	Coordinator
Ms.	**Schweitzer**	Ingrid	Germany	1	
Ms.	**Serra**	Maria	Italy	3	
Mr.	**Serrano**	Antonio	Spain	3	
Ms.	**Shurelova**	Yana	Bulgaria	2	

Mr.	**Stadler**	David	Switzerland	2
Ms.	**Starakis**	Ioannis	Greece	1
Mr.	**Taylor**	Bernard	UK	2
Mr.	**Tokar**	Jan	Poland	1
Ms.	**Tsankova**	Albena	Bulgaria	3
Ms.	**Turricchia**	Angela	Italy	1
Mr.	**van Bergen**	Henry	Netherlands	3
Ms.	**Vinuales**	Eder	Spain	2
Mr.	**Welz**	Wolfgang	Germany	Overall coordination
Ms.	**Wodzinski**	Rita	Germany	1
Ms.	**Zweifel**	Stefanie	Germany	Overall coordination

Feedback Questionnaire

Publication "Teaching Science in Europe"

Please complete this questionnaire and post it to:
Science on Stage Deutschland e.V., Poststraße 4/5, 10178 Berlin, Germany or fax it to ++49 – (0)30 – 4000 . 67. 35.

Country:

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- Germany
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- The Netherlands
- Norway
- Sweden
- Switzerland
- Spain
- Czech Republic
- Other country: ....

School level:

- Primary Level
- Secondary Level I
- Secondary Level II
- Other: ....

Teacher of: *(If applicable, you can select more than one subject)*

- Biology
- Chemistry
- Physics
- Technology
- Mathematics
- Other: ....

Do you find this publication inspiring for your work?

....

Do you like the format of the booklet?

....

Which question(s) or which topic(s) would you like to work on in a European teachers' workshop?

....

....

....

....

Thank you very much for your time!

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The non-profit organisation Science on Stage Deutschland (SonSD) establishes a network for German science teachers, promoting exchange with pedagogues from other European countries. It organises workshops and training programmes to disseminate interesting experiments and new teaching concepts from all over Europe in Germany. The organisation invites teachers working on particularly interesting projects to participate in the international education festival "Science on Stage", hosted by the seven largest multinational research organisations in Europe.

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