Material properties – A research expedition

A learning module of the iMINT-Akademie (STEM Academy)

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Image: “Professor”

Image: The “Beagle”

Image: “World map”

1 Documents

Word files

- Material properties – A research expedition – Didactic information for teachers
- Worksheets, teacher informations, transparencies, and hints for learning environments 1 to 3

Sound file

- Material properties – foghorn and ocean waves (sample audio clips)

2 General preliminary remarks on the "Material properties – A research expedition" unit

2.1 Subject-related knowledge

The materials, which include notes, experimentation instructions, and methodology tools, have been developed in accordance with inclusive standards and enable editing with respect to different levels of educational readiness.

The "Material properties – A research expedition" topic in this project for grades 5 and 6 is handled using three relatively independent learning environments.

Learning environments invite students to a self-directed learning process in close cooperation with one another. In this process, the students work through open-ended tasks against the backdrop of prepared learning materials and media.
The role of the teacher changes. He or she acts as an organizer, partner, and advisor.
During the learning process, the students are encouraged to solve problems using individual, creative, and, above all, independently selected approaches.

- All students work through the same task. This task takes into account the heterogeneity of the students and offers a low starting threshold as well as subtasks for further study at a different level of understanding and abstraction. The individual working and learning paces are respected.

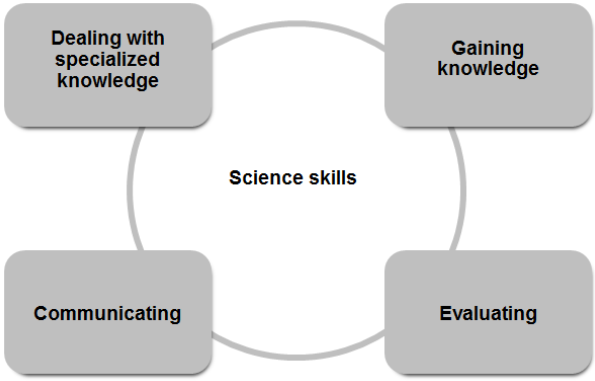
- The main focus is on the students' individual approaches. The students themselves decide on the use of working media and the type of documentation.

- The mutual exchange about the different ways of processing a task is essential so that the students can reflect on their different solution strategies. Understanding is deepened as a result of reflection.

The "Material properties – A research expedition" teaching unit consists of three learning environments that follow a background story in which the oceanographer Prof. Cousteau goes on a journey around the world on her research ship, the Beagle. Each learning environment starts with an e-mail from the professor. In the e-mails, the oceanographer asks the students to support her in sorting materials (learning environment 1), investigating materials (learning environment 2), and classifying the properties of materials (learning environment 3). The low-threshold starting point for learning environment 1 allows all students to participate in the topic of "properties of materials." Collaborative organizational formats in all three learning environments and differentiated tasks

ensure that students at different performance levels are collectively involved in accomplishing the tasks. The first and second learning environments have an open design that allows the students to find their own ways to solve the tasks.

In dealing with phenomena from nature and technology, the students develop scientific questions and acquire basic scientific skills that can be divided into four skill areas of science education:



The learning environments of the “Material properties – A research expedition” project endeavor to develop all skill areas, but they give priority to gaining knowledge. It is hard to imagine any learning environment that does not include dealing with specialized knowledge, communication, and evaluation.
The framework curriculum of Berlin/Brandenburg designates defined **standards** (only available in German) for the skill areas specified above.
These standards describe at different levels the skills that students acquire from subject teaching over the course of their schooling, depending on their learning conditions, and on what degree or educational transition they are working toward and in what time frame.

In every learning environment of this project, the targeted skills and ascribed standards can be inferred from the didactic part of the materials.

2.2 Value formation in STEM teaching

2.2.1 Value formation in school, or why are values important?

Whenever people work and live together in society, in families, and at school, these interactions are based on values. There is not a single area of life where we can do away with values. Independence, a sense of responsibility, the ability to reason, tolerance, and team spirit are necessary skills that are essential for successful personal and professional development. Having these values primarily means taking them seriously, living them out, and advocating them. The indispensability and major significance of values makes it necessary to give value formation an important role in lessons at school.

2.2.2 Implementation in these materials

A wide range of values appears to be suitable for science lessons. The following values in particular are highlighted in this teaching unit: responsibility, team spirit, tolerance, and dependability. These values are relevant to the learning process in these materials. Values relevant to the learning process play a fundamental role, both in interaction with one another and in independent action**. All three learning environments focus on these values and thus aim to encourage value formation.**

The value and its importance	Implementation in these materials
Responsibility ... means bearing the consequences for one's own decisions and behavior.	▪ Conducting the experiments responsibly ▪ Handling the provided materials responsibly ▪ Accepting responsibility for preparing and conducting the experiments
Team spirit ... means cooperating successfully and effectively.	▪ Making one's best contribution to a solution to the task ▪ Providing mutual support while conducting the experiments ▪ Going up to others and offering to help ▪ Listening to others without interrupting them
Tolerance … means recognizing different opinions.	▪ Accepting different learning paces and levels ▪ Discussing solutions constructively
Dependability … means keeping a binding agreement.	▪ Being able to rely on one another ▪ Precisely following specified instructions and performing tasks punctually ▪ Obeying established rules and agreements ▪ Putting away materials and cleaning the workstation

3 Overview of the unit

Learning environment	Approximate time needed in hours	Topic and learning content	Student activity/organizational format
1	2	Sorting materials	Group work: Development of own, reasonable sorting criteria
		Becoming acquainted with the possibility of sorting by “material,” “property,” and “functions”	Museum tour, evaluation of the sorting systems with the class as a whole
2	3	Seeking materials with specific properties for various problems	Group work with separate responsibilities, students independently develop experiments for investigating different material properties, support through incremental hints, word lists
	1	Presenting experiments and results, practicing using technical vocabulary	Students
3	2	For each material, compiling all properties investigated so far and additional information	Group work with separate responsibilities, experiments at stations, creation of material fact sheets, including with informational resources
	1		Challenge for evaluating the fact sheets

4 Specific didactic information

4.1 Materials

Samples of as many different materials as possible in different forms are needed for sorting (learning environment 1) and for the experiments (learning environments 2 and 3). The larger the range of material samples, the more the students must think about and discuss the criteria they will use to sort the materials in learning environment 1. Plastics aside, it would be good to include materials with similar colors, for example, to support sorting by colors. Strings made of different materials would also be good (sorting by function: binding together). It makes sense to select plastics of different colors so that the students can classify the plastics more easily.
The three different plastics were chosen because of their different densities and easy availability. The density of PP (polypropylene) is about 0.9 g/cm³, so it floats on water. PET (polyethylene terephthalate) has a density of 1.38 g/cm³ and sinks in water. With a density of 1.05 g/cm³, PS (polystyrene) sinks in freshwater and floats on saltwater (key factor in the “underwater probes” problem in learning environment 2).

The following materials are recommended for learning environments 1 and 2:

Material	Products
Aluminum	Tea light cup, aluminum foil
Cotton	String, T-shirt
Iron	Paper clip (silver, magnetic), nail
Flax	Gift ribbon, string
Glass	Marbles, small decorative stones, microscope slides
Wood	Spatula, chopsticks
Ceramic	Cups, plates
Cork	Coaster, bottle cork
Copper	Wire (orange-red)
Leather	
Polyethylene terephthalate (PET)	Several disposable bottles Recycling code 1
Polypropylene (PP)	Some place mats, cords, packaging, e.g., yogurt containers, outer packaging for sausage and cheese Recycling code 5
Polystyrene (PS)	CD jewel cases, some coffee cups, some plates, packaging, e.g., yogurt containers Recycling code 6
Wool	As yarn

The materials can be handed out to the students in pieces measuring approximately 10–20 cm^2 or in natural form (paper clip). We recommend providing all the objects for each group in a bag or box.
The worksheets for the students include a word list with photographs and names of the materials. The photos should be adapted for the current samples.

For learning environment 1, the experimentation materials are set up in the room accessible to all groups. Since the groups develop their own experiments, the materials are not sorted by experiments. It makes sense to label any materials not yet known. The groups mainly obtain the materials for the experiments from the box of materials for learning environment 1. For the group assigned “heat,” it is crucial that the material samples for the thermal conductivity experiment be of a uniform size to ensure comparability. For the group assigned “shark,” the material samples for the hardness test must allow scratching with a ruler and iron nail.

In learning environment 3, the experimentation materials are provided based on the experimentation instructions.

“Buoy” group/electrical conductivity
- Three cables (2 blue, 1 red) with two alligator clips
- Incandescent bulb/socket
- Lantern battery
- Petri dish

“Lifeboat” group/magnetism
- Strong magnet
- Beaker

“Underwater probe” group/behavior in water (density)
- Plastic cup/beaker
- Spatula
- Glass rod/spoon
- Tweezers
- Large beaker
- 500 g of table salt

“Heat” group/thermal conductivity
- Thermometer
- Stopwatch
- Electric kettle
- Standard beaker
- Paper towels
- Butter
- Blunt knife
- Pieces of the following materials, at least 12 cm long, at least 0.5 cm wide, not round: **hard plastic** (e.g., spoon, wide zip ties made of nylon), **fabric, wood, iron, copper, aluminum** (e.g., “unwind” the edge of the tea light), if possible, **glass** (microscope slide or similar), **ceramic** (e.g., magnesia groove, larger fragments)

“Shark” group/hardness
- Large iron nail
- Ruler
- Materials for testing, similar to the materials for the “heat” group, but they do not have to be quite as long (allow scratching)

“Cook” group/behavior in water (solubility) and “filtering and boiling down” methods of separating materials

- 5 g of table salt
- Coarsely ground pepper/peppercorns
- Butter
- Glass rod/spoon
- Funnel
- Filter paper
- Tea light
- Metal teaspoon
- Possibly a conical flask
- Matches

4.2 Inclusive aspects

In all learning environments, the basic organizational format is group work, which ensures the students’ cooperation as well as joint mastery of the tasks. The low-threshold starting point for learning environment 1 makes every group member an expert at the first task, since they all collectively find a sorting system for the materials that are presented in newly formed groups during the closing museum tour. The open-endedness of the task without a specified structure allows each student to participate in mastering this task. Dealing directly with the materials is extremely challenging for all students.
In learning environment 2, groups of students with similar abilities are assigned tasks with varying degrees of difficulty. Therefore, all students are involved in the solutions to Prof. Cousteau’s many problems according to their capabilities, since one group cannot possibly solve all the problems.
By contrast, in learning environment 3, groups of students of mixed abilities ensure that the students mutually support each other with the complex tasks.
The presentations in learning environments 2 and 3 can be prepared independently by all students since word lists and sketches are provided.

4.2.1 Support for students with dyslexia

Symbols for the material properties to be investigated run through the entire unit and enable students who have difficulty reading to identify and recognize the topics.
In learning environment 3, particular properties of a material can be investigated in an experiment, while other properties must be read from classification cards with text and tables. The classification cards are prepared in such a way as to provide two levels for the tabular format and two levels for the text format.
The terms in the word list (learning environment 1) are formatted with syllables in two different colors, which makes them easier to read for students who have difficulty reading. Printing these pages in color is very useful. If this is not possible, however, the syllable formatting can be replaced with bold/regular formatting for black-and-while printing. A font size of 14 has been used throughout to facilitate reading.

4.2.2 Fostering fast learners

As the students work through the learning environments, they will raise questions to the group. These questions should be collected and displayed in the classroom. They are useful as subjects for additional research for students who achieve results quickly. Possible topics might include the following:

- Jacques Cousteau
- The historical journey of the Beagle
- Various species of jellyfish
- The saline content of the oceans
- The development/production of cork, bast fibers, etc.

The results can be presented, for example, as a poster as part of the museum tour in learning environment 3.

4.3 Language development and language education aspects

All three learning environments include information on developing the acquisition of language skills.

Learning environment 1: The low-threshold starting point allows all students to participate linguistically, that is, they must discuss what criteria they use for their sorting system and which umbrella term they use for their categories.
Then they write a letter in which they must support and objectively substantiate their decision with clear arguments. Each student can give a brief presentation with the aid of his or her notes. Afterwards, the students acquire knowledge of the technical vocabulary related to the materials and can enter them in a table.
For better orientation with the many different materials in the box of materials as well as the correct terms for naming the materials, the students are given a list of words with images of the material samples in one column and their names in the other column.

Learning environment 2: This learning environment also begins with a low-threshold approach to linguistically establish a link to the students' experiences. Small symbols for the respective problem are used on both the problem cards and the hint cards. This enables each student to participate. The problem cards encourage the students to extract information and develop a question, that is, they must take a position on an issue and formulate and give reasons for hypotheses. The students interact again and must verbally discuss the hypotheses with each other.
A worksheet provides assistance for the presentation by giving the students both visual elements (specifically in this case, symbols for the material properties) and linguistic formulation aids that enable them to objectively, i.e., scientifically, present and give reasons.

Learning environment 3: This learning environment calls on the students to interact again. During experimentation, the students are encouraged to take notes that they will need for the fact sheet they are to create. In the newly assembled groups, the experts from learning environment 2 may possibly explain the experiments conducted at the stations.
Guidelines for structuring the fact sheets serve to develop writing strategies and enable the students to create the fact sheets based on text samples. Classification cards written at different levels make it possible for each student to participate linguistically. First, the students must extract

information from tables. Then, for the higher levels, the students must apply reading techniques and strategies in line with the reading goal.
Finally, the students are challenged linguistically by explaining, giving reasons for, and evaluating the fact sheet posters.

4.4 Focus of skill acquisition

According to the framework curriculum of Berlin/Brandenburg, the “Material properties – A research expedition” teaching unit focuses on knowledge acquisition at levels C and D. The unit lends itself to grades 5 and 6.
The following knowledge acquisition skills are fostered:

- Observing, comparing, sorting
  - C: Describe observations
  - C/D: Sort, compare, and describe facts/objects using specified criteria
- Conducting scientific investigations
  - C: Conduct specified experiments under guidance
  - D: Plan and conduct experiments to test hypotheses according to specifications
  - C: Describe findings
  - D: Describe findings with reference to the hypothesis
- Applying elements of mathematics
  - D: Gather variables from source materials (for example, texts and tables) and state them with units

4.5 Background story

The story of oceanographer Prof. Cousteau integrates the entire “Material properties – A research expedition” unit in a background story of a highly challenging nature. In each motivation phase, the students are reintroduced to the situation through visual and auditory media, and they receive an e-mail from the professor with the task to collectively help her. The collective action in the interest of the professor runs through the entire unit and all learning environments. Due to the repetition of the introduction in all three learning environments, the students’ ability to remember is enhanced and the starting point for the new problem is made easier.
The background story is an invented story with an entertaining character. Oceanographer Cousteau’s character is entirely fictitious. The invented background story is designed to encourage the students to become involved in the topic of material properties. The background story supports the motivation, retention, and emotional involvement of all students. The request for help especially appeals to students who are motivated by a willingness to help and by the opportunity to put their own skills into practice.
The background story provides the students with an introduction to the topic that touches them on an emotional level, and that appears only in the teaching sessions aimed at motivating the students for the tasks. In the subsequent teaching sessions, the students deal solely with investigating and describing material properties in objective contexts.

4.6 Use of the media

All visual media intended for the entire class (image of the Beagle, image of Professor Cousteau, image of the world map) can be presented using a smart board, video projector, document camera, overhead projector, or paper printout on a board, depending on the equipment in the classroom. The auditory media (foghorn and ocean waves) can be played as MP3 files or on a CD.

(Source of the sounds: Ocean Cruise Liner Ship: 2/17/2016, 7:29 PM http://www.freesound.org/people/TiredHippo/sounds/317386/ current as of: 9/30/2016 (TiredHippo, license: CC0), original file name: 317386__tiredhippo__ocean-cruise-liner-ship.mp3 oceanwaves-5.wav: Current as of: 2/17/2016, 7:32 PM http://www.freesound.org/people/Rmutt/sounds/148283/ (Rmutt, license: CC BY-SA-NC 3.0), original file name: 148283__rmutt__oceanwaves-5.wav)
The world maps show the professor's route on the world's oceans. The maps also illustrate the locations of the problems that the students must solve in learning environment 2.

4.6.1 Use of the worksheets

Learning environment 1: The use of the worksheets is based on the objective of the action. In learning environment 1, one tracking sheet for the group work is provided to each group. The group uses the worksheet to classify the different sorting systems during the museum tour. By contrast, the "Sorting the materials" worksheet is used to solidify the results. It ensures that the students know that materials can be differentiated by material class, property, and function. The scientific concept of "material" and the technical term "material properties" are introduced at the end of learning environment 1. Each student receives this worksheet at the end.

Learning environment 2: The students come up with their own experiments in order to investigate materials for particular properties. The students must report their results to their classmates in a presentation and decide which material they will recommend to Prof. Cousteau to solve her problem. Preparation of the presentation's content is prestructured using one worksheet per group.

4.6.1.1 Incremental hints

The incremental hints are based on the specifications of Dr. Lutz Stäudel*. They promote self-directed learning by offering the students step-by-step support in solving their problems, but they also simultaneously allow individual paths of learning and solving since the students are not required to use all or any of them.
The prompts given in the incremental hints are always structured in the same way. There are four incremental hints for each working group. The first hint card encourages the students to reformulate the problem for themselves within the group and gain clarity about the task, that is, about the material property that must be investigated for the problem. All prompts are intended to give the students hints so that they can come up with a structured, scientific solution. For high-achieving groups that have completed the task without hints, the last incremental hint (the experiment setup or conducting the experiment) can be used to check their own solution.

* Dr. Lutz Stäudel is an author from Leipzig, Germany. He worked at the University of Kassel from 1976 to 2011 in the field of chemistry teacher training. After completing his studies in chemistry, psychology, and education in Giessen and Kassel, he gained experience in a pilot environmental education program in the town of Baunatal and in chemistry education of intermediate and top grades. In recent years, he has been involved in numerous scientific projects and in the field of instructional and school development (SINUS, Increasing Efficiency in Mathematics and Science Education). His current work focuses on the "Development of Learning Tasks for Science Lessons," the "Teaching Area of Natural Sciences," and method-oriented school-based training. He is an associate editor of the journal Unterricht Chemie (Chemistry Instruction) and the Friedrich Jahresheft (Friedrich Annual).

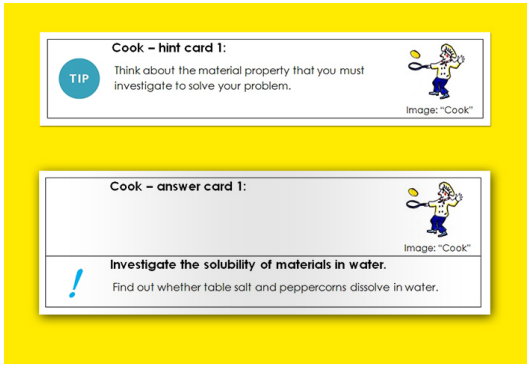


Image: “Hint card 1”

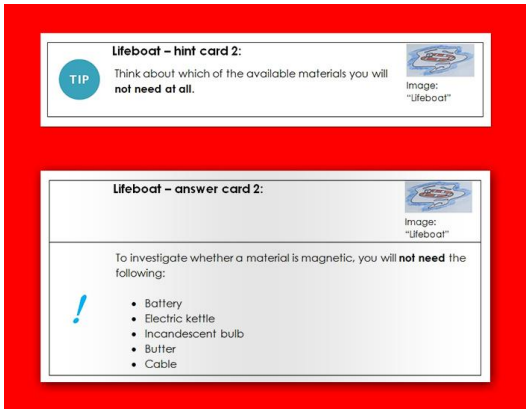


Image: “Hint card 2”

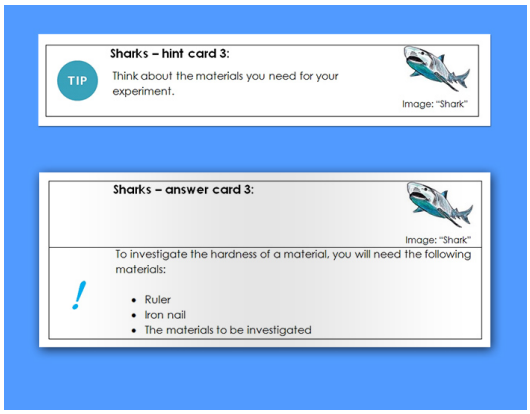


Image: “Hint card 3”

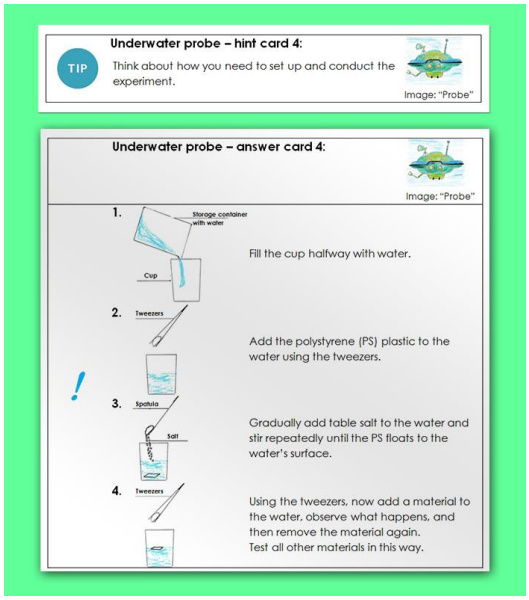


Image: “Hint card 4”

The “cook” problem is an exception. In this case, there are five incremental hints since the task has two parts (investigation of the material property and subsequent material separation). The fifth hint does not describe the process of separating materials, but it lists the required materials. This problem is intended for high-achieving groups so that they can separate the materials based on the hint. If necessary, the teacher can also hand out the experimentation instructions (incremental hint “cook” 5b, separating materials).

The students should not be allowed to immediately access the incremental hints. Therefore, it makes sense to not make all hints available at the same time. Storing the hints near the teacher’s desk, for example, in envelopes, is a good idea. For a better overview, using different colored envelopes is recommended. The prompt is always on the outside of the envelope and the matching answer is inside the envelope.

Image: “Envelopes”

In this way, the students are encouraged to think about an answer to the prompt on their own before they consult the answer. This especially makes sense for learning groups that have not yet worked with incremental hints.

4.6.1.2 Station cards

Learning environment 3: Each station where the students investigate their material is provided with the necessary equipment and instructions for the experiment.

4.6.1.3 Fact sheets

In order to design the fact sheets, the groups receive a template that specifies the structure of the contents. The students can freely design their fact sheets.

4.6.1.4 Classification cards

The students are expected to present additional information in the fact sheets that cannot be investigated in an experiment during class. The students receive this information from the teacher as classification cards with tables showing the boiling and melting temperatures. Additional information is provided in text format, such as deposits, use, and special features. The tables and texts are each available in two levels that the teacher uses based on his or her assessment of the learning conditions.

- Classification card 1: The table contains only the investigated materials.
- Classification card 2: The table contains additional materials.
- Classification card 3: The text is subdivided.
- Classification card 4: The text is not subdivided.

5 Assessment possibilities

The experimentation and deliverables in learning environments 2 (presentation) and 3 (poster) are useful for the assessment. For this purpose, the students must be familiar with the rules for good experimentation, good presentations, and good posters, and these rules should be displayed in the room, for example, on a poster.
Due to the open-ended nature of the task and the entertaining introduction to the unit, learning environment 1 is not very suitable for assessment. The challenge at the end of learning environment 3 is not suitable as a basis for assessment. It simply serves to acknowledge the results of the group work, meaning the created posters, and to gather information. With the exception of targeted reading and filling in cloze tests, etc., the students are not required to perform independently.

5.1 Checklist: How do I create a poster?

No.	Information	Com-pleted
1	The most important information first – the heading Write the heading of your poster clearly and in large letters so that others quickly see what the topic is. Block letters are better than cursive writing.	☐
2	Keep it short! Do not write a lot of text. Short sentences are easy to read and stick better in the reader's mind. Keywords are often enough.	☐
3	Subdivide the text Divide the topic into sections. Related content can be collected under a subheading.	☐
4	A picture says more An image related to your topic provides the eye-catcher for your poster. Design your poster with the image so that it attracts attention. You are sure to find fitting images that make your topic look as interesting as possible. However, use images sparing-ly. A poster is not a photo album!	☐
5	Create order Images and texts should not be randomly jumbled. Use colors and symbols (for example, arrows or dots) to partition and organize the space on your poster. Tip: It also looks good if you display the individual topics on colored sheets of DIN A4 paper and arrange them accordingly, similar to the arrangement on the front page of a newspaper. Limit yourself to a few colors.	☐
6	Drawings help explain Some things cannot be described with words or photos, in which case you can draw something yourself.	☐
7	Less is often more A poster should not be too full and overloaded. Dare to use gaps: Empty spaces help with the structure.	☐

6 Safety information

Learning environment 2: The “buoy” group conducts an experiment with a 4.5 volt battery. Care must be taken to ensure that a short circuit does not occur, meaning that no load, such as an incandescent bulb, is inserted in the circuit because the battery and the cable could overheat in this case.
The “heat” group works with an electric kettle and very hot water. The teacher should always handle the electric kettle. A quiet “corner” where the students can avoid bumping into each other would be good for this group.
The “cook” group can experiment with a candle. Teacher supervision is particularly important here. For the “cook” problem, coarsely ground pepper or peppercorns should be used; otherwise, there is a risk that powdered pepper could get in the students’ eyes and cause eye irritations.

Learning environment 3: When learning at stations, the students conduct the same experiments as for learning environment 2. Therefore, the same safety information applies. The stations now cover electrical and thermal conductivity.

List of pictures

Images	Author
Professor, Beagle, World map, Hint card 1, Hint card 2, Hint card 3, Hint card 4, Envelopes	Anke Travers for the iMINT-Akademie for the Senatsverwaltung für Bildung, Jugend und Familie Berlin/Siemens Stiftung, CC BY-SA 4.0 international