KLEINE FORSCHER
Naturwissenschaften und Technik für Mädchen und Jungen

LIGHT, COLOURS, VISION – EXPLORING OPTICS

GEFÖRDERT VOM

Bundesministerium
für Bildung
und Forschung

PARTNERS

Helmholtz Association Siemens Stiftung Dietmar Hopp Stiftung Deutsche Telekom Stiftung Autostadt GmbH

“HAUS DER KLEINEN FORSCHER” FOUNDATION

Since 2006, the non-profit “Haus der kleinen Forscher” (Little Scientists’ House) Foundation has been actively engaged in promoting better education for children between the ages of three and ten in the areas of science, mathematics, and technology. The Foundation has set itself an ambitious objective – namely, to enable all children between the ages of three and ten to have day-to-day encounters with science, mathematics and technology topics. It aims to give these children the opportunity to discover this exciting field for themselves in an enjoyable way. With a nationwide professional development programme, ideas, and a steady flow of new pedagogical resources, the “Haus der kleinen Forscher” Foundation supports early childhood educators and primary school teachers in fostering children’s spirit of discovery and in accompanying them in their inquiry activities in a qualified way. Here, we focus both on joint learning and inquiry on the part of the children and of the adults, as facilitators of learning, and on learning itself.

The integration of the Foundation’s offerings into the everyday lives of children between the ages of three and ten fosters not only their understanding of science, mathematics, and technology but also the development of their language, learning, personal, social, and fine motor skills. In this way, the Foundation wants to contribute with its offerings to improving educational opportunities, to fostering the next generation of professionals in the STEM fields, and to professionalising teachers and educators. The development of the professional development programme and the pedagogical resources of the “Haus der kleinen Forscher” Foundation is informed not only by the specifications of the education plans and curricula of the German federal states (*Länder*) but also by current research findings in the areas of developmental psychology, early childhood education, learning research, and subject-specific didactics. Moreover, it draws on a wealth of practical experience and substantive suggestions gathered a) at the seminars for the trainers who deliver our professional development workshops, b) during regular visits to early childhood education and care centres, after-school centres, and primary schools, and c) within the framework of training observations in the Foundation’s local networks.

The Foundation’s partners are the Helmholtz Association, the Siemens Stiftung, the Dietmar Hopp Stiftung, the Deutsche Telekom Stiftung, and the Autostadt in Wolfsburg. The Foundation is supported by the German Federal Ministry of Education and Research.

CONTENTS

FOREWORD

Dear teachers and educators,

As a child, when I couldn't get to sleep at night, I would use a flashlight and my hands to cast shadow figures onto the bedroom wall. Of course, these silhouettes were always completely black. So I can remember how fascinated I was one day at primary school when we saw a shadow play where coloured images were conjured onto the back of a screen. That same evening, I started my own experiments with coloured tracing paper and my bedside lamp. Naturally, it wasn't half as good or as colourful as the shadow play in school, but I had fun trying things out.

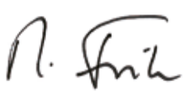
The title of this brochure is "Light, Colours, Vision – Exploring Optics". Light, colours, and vision play an extremely important role in our lives. Yet we seldom pay much attention to them. In order to discover their wonders, we must consciously think about our eyes and the way they work. Together with our sense of touch and hearing, eyesight is the best way for humans to gather impressions of the outside world.

Even our language indicates how fundamental light and vision are for us: A "leader of vision" has unusual competence in discernment or perception, and somebody who is a bit slow on the uptake is "not the brightest candle on the cake".

If we look at the world through the eyes of a child, we can rediscover many phenomena that are as mundane as they are amazing: Why do we need light to see? Not all light sources are the same – why and how do we see when it is quite dark? Can I predict how colours will mix? And does this work just as well with water colours as with food colours?

The present topic has many important links with various science disciplines. Physiology is relevant to our understanding of spatial vision. Optics, a subfield of physics, teaches us fundamental facts about the diffraction and refraction of light. However, these facts are only the first steps on the road to electromagnetism and, later, to quantum optics. The scaling, storing, and digital transmission of images is of paramount importance.

As you can see, the complexity of the topic is enormous. With this brochure, we want to give you some ideas about how you can explore and investigate the diversity of this thematic area with the children. We want to encourage you to conduct projects with your group that focus on optical phenomena. I hope that you and the children will have as much fun with light and all the things you can do with it as I did in my primary school days.



Michael Fritz
Chairman of the Executive Board of
the "Haus der kleinen Forscher" Foundation

ABOUT THE BROCHURE

"Light, Colours, Vision – Exploring Optics" is a topic that has a great impact on our lives. Without light there would be no life on the surface of the Earth – neither plants, animals, nor humans could survive. Day and night, light and darkness, determine our rhythm of life. Most people perceive over two-thirds of all information from their environment with their eyes – that is, their sense of sight. And colours play a decisive role in this regard. They provide important information about the objects and living things that surround us. Hence, our everyday experiential word offers lots of opportunities to pursue in more depth the topic of "Light, Colours, Vision – Exploring Optics". This brochure aims to support you in doing so.

The brochure begins with a brief presentation of the points of contact with the topic of "Light, Colours, Vision – Exploring Optics" in everyday life at early childhood education and care centres, after-school centres, and primary schools, and the links with the contents of the education plans and framework curricula of the German federal states (*Länder*). It then addresses the child's perspective. How does children's vision develop? How are visual perception and learning connected? What ideas and interests do children between the ages of three and ten have in relation to the topics of light, colours, and vision?

Project work is a good way of accessing the many aspects of the topic. It gives the children and yourselves, as teachers and educators, an opportunity to play an active part and to bring your individual strengths and interests to bear. And it enables long-term and holistic engagement with a topic. For this reason, one section of the brochure deals with the project approach and provides supporting methods and background information.

In the practice-related chapter of the brochure, projects on the subject of "Light, Colours, Vision – Exploring Optics" from various educational institutions are presented. This presentation is supplemented with diverse suggestions and ideas for further exploration and inquiry activities. As usual, interesting background information and recommendations for further reading round off the brochure. We hope that you will enjoy reading it and that you will find many exciting ideas for your pedagogical work. So keep your eyes open and start investigating!

LIGHT, COLOURS, AND VISION IN EARLY CHILDHOOD EDUCATION AND CARE CENTRES, AFTER-SCHOOL CENTRES, AND PRIMARY SCHOOLS

POINTS OF CONTACT WITH THE TOPIC IN EVERYDAY LIFE

From everyday life, children are familiar with many optical phenomena. They experience that it is bright during the day and dark at night. They notice that they perceive the colours of toys, furniture, and other objects differently at dusk or in the dark than in daylight. When it's dark, they use artificial light sources – they know, for example, that they can use candles or flashlights to light up a room. And from night hikes they are familiar with how eerie darkness can be.

Children like to draw with coloured pencils and drawing ink. When doing so, they observe how the colours look on the white paper. Younger children like to sort their toys by colour. Older children notice that the colours in nature differ in spring, summer, autumn, and winter. Children study the food on their plates carefully to see what colour it is; the younger ones stick their fingers into tomato ketchup, spinach, and raspberry jam. At primary school age, many children have a favourite colour; some of them are already familiar with vibrant light colours from the theatre or the children's disco.

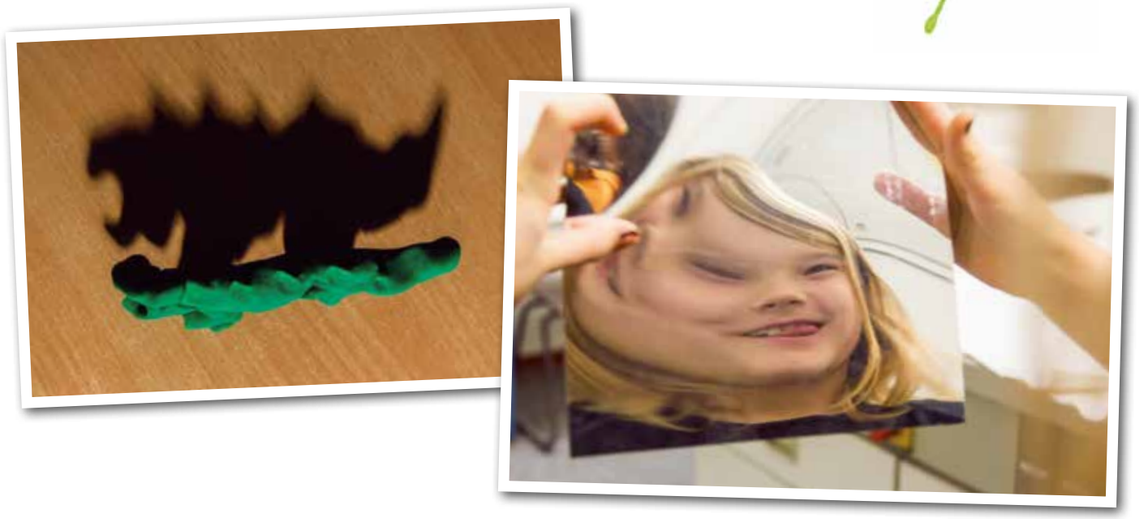
Children also get a lot of pleasure out of optical illusions and 3D images. Some children have to start wearing glasses at pre-school or primary school age. They like to look at themselves in the mirror and to clown around in front of it.

Behind all these everyday experiences are optical phenomena such as light and darkness, light sources, mirrors and mirror images, light colours and object colours, vision, and the deception of the sense of sight. These are topics with which the children are already familiar from their diverse experiences and observations. These (and many other) basic everyday experiences can be taken up at early childhood education and care centres, after-school centres, and primary schools and examined in greater depth during joint explorations and investigations.

Late one afternoon in autumn, two kindergarten children are on their way home. It is dark; the street lamps light up the pavement. The children notice that they are being followed by their own shadows – their shadows move when they move. Sometimes their shadows walk behind them; sometimes they are even in front of them; sometimes they are long, sometimes short.

The children start to play with their shadows and they discover that when they walk towards the street lamp, their shadows are behind them and they decrease in length. When they stand directly under the lamp, their shadows are "lying" beside them and are short. And when they move away from the street lamp, their shadows are in front of them and get longer again.

LIGHT, COLOURS, AND VISION IN THE EDUCATION PLANS AND FRAMEWORK CURRICULA OF THE GERMAN FEDERAL STATES



Pre-primary level

The topics of light, colours, and vision can be found in almost all the education plans and framework curricula of the German federal states (*Länder*). They feature aspects such as perception, sense of sight, light and darkness, and the properties of light (propagation, reflection, refraction, etc.).

At pre-primary level, children have basic experiences in the thematic area of "Light, Colours, Vision". All education plans provide for engagement with questions about inanimate nature – for example about physics, to which phenomena of light and colour belong. They include various aspects of the topic, such as:

- Without light we cannot see anything (light and darkness; day and night; sunlight and warmth)
- Light and mirrors (mirrors reflect light; flat and convex mirrors; distorted mirror images, etc.)
- Light and colours (light contains many colours; the colours of sunlight; signal colours; colour mixtures; natural colours)

Primary level

Building on the comprehensive basic experiences gained in early childhood education and care centres, the content of the topic "Light, Colours, Vision – Exploring Optics" is expanded later at primary school. There are four major thematic areas in the framework curricula for primary schools:

- Perception of the world via the senses: the sense of sight, the eyes
- Light and life: adaptation on the part of plants, animals, and humans
- Properties of light: reflection, refraction, propagation, focusing
- Light and shadow

The thematic focus of the curricula differs from state to state. In the framework curricula of the states of Saxony-Anhalt and Schleswig-Holstein, for example, the sense of sight has priority. They propose that sensory and adaptation performance in humans be investigated and inquiry activities relating to the eye be conducted.[1]

Light plays a role in many areas of life. Day-night rhythm, for example, influences the way of life of humans and animals. The framework curriculum of the state of North Rhine-Westphalia takes this up and proposes that the children investigate and describe the importance of light for humans, animals, and plants.[2]

The properties of light and the observation of natural light sources are a key focus of the framework curricula of the Saar State and Bavaria, among others. These curricula propose, for example, that students investigate the spectral colours, conduct inquiry activities with prisms, explore the cause of the cycle of day and night, and address the topic of the sun as a star.[3]

Links to other education areas

All the education plans and framework curricula of the federal states recommend that the topic be linked to many other education areas so that the children can acquire a comprehensive understanding. For example, there are cross-links between the topic and a) technology (the generation of light and the invention of artificial light sources; mirrors of all kinds; photography), b) colours and art (creativity with colours; extracting colours from natural materials; mixing different colours), c) language education (describing experiences; naming objects; rhymes, songs, stories, and fairy tales), and d) history (light sources through the ages: candles, oil lamps, etc.).

Project work is a very suitable way of achieving such a comprehensive perspective with children of pre-primary and primary school age. It enables a topic to be dealt with over a long period of time; a new focus can be set time and again; and other educational areas can be incorporated (see the next chapter on project work). With the practical ideas and suggestions in the present brochure, the "Haus der kleinen Forscher" Foundation wishes to encourage teachers and educators to take up the topics of light, colours, and vision in projects and to implement them with the children.

[1] *See framework curriculum (RLP) of Saxony-Anhalt and Schleswig-Holstein.*
[2] *See framework curriculum (RLP) of North Rhine-Westphalia.*
[3] *See framework curriculum (RLP) of the Saar State and Bavaria.*

THROUGH THE EYES OF THE CHILD

In order to be able to support children well in their development and learning processes, it is important to be aware of, and to take up, their prior experiences and their interests and abilities. When observing children, you should therefore pay close attention to their spontaneous actions, to what fascinates them, and to the things that they are occupied with at that moment in time.

THE DEVELOPMENT OF VISION

Like adults, children perceive everything that surrounds them with their senses. The sense of sight plays a major role in this regard. Compared to the other senses, the development of vision occurs relatively late in a child's development. The eyes do not open until after birth; at first, babies perceive only objects with very high contrast. However, between three and four months of age, the sense of sight matures very quickly, and by the age of one the child's vision is almost fully developed. The table below provides an overview of the individual visual abilities.[4]

Ability to see	• *Shortly after birth, infants look around and appear to be looking at the objects in their field of vision.* • *At first they can see objects sharply only if they are not more than 20 to 25 cm away.* • *Between six and eight months of age, visual acuity reaches adult levels.*
Light (bright and dark)	• *At the age of seven months, the foetus in the womb is sensitive to light, reacts to light stimuli, and can distinguish between light and dark.* • *During the first months of life, infants can distinguish different brightness levels.*
Shapes	• *The ability to distinguish different brightness levels enables infants to better perceive contrasts and shapes. They prefer looking at distinctive patterns – for example chessboard- or striped patterns – than at uniformly coloured surfaces.* • *Infants have a preference for human faces and face-like shapes. At first, infants can focus only on the edges of the face, such as the hairline and the chin, as these are particularly high-contrast areas. From about the second month of life, infants can also perceive the middle of the face in detail.*
Colours	• *Newborn babies like to look at colourful things. However, they are not yet able to distinguish individual colours well.* • *By the age of two months, they learn to distinguish red, blue, yellow, and later green.* • *At about four months of age, they can perceive the entire colour spectrum.*
Depth perception	• *The ability to perceive the distance and the depth of objects in space is a very complex achievement. It enables us to perceive the world in three dimensions although the images formed on the retina of the eye are two-dimensional. Although depth perception appears to be an innate ability, it can be trained and further developed through self-produced movement. At the age of six or seven months, most children are able to distinguish deep and shallow areas and to avoid so-called "falling-off places" that appear dangerous.*

[4] *See Berk, L. E. (2005); Konrad, K., Fink, G. R. (2008)*

VISUAL PERCEPTION AND LEARNING

Vision has many functions

Vision helps both children and adults to understand and engage with their environment. It fulfils various functions. First, vision enables us to determine where things are located and to orient ourselves. For example, where are things located in our immediate surroundings or in distant space? Where is the ball? Where is the house in our street? Where am I in relation to the doll that I want to pick up? And so forth. Second, our sense of sight is the one that we usually use to recognise and identify objects, living things, and characteristics: Who or what is that? And how can I recognise a certain person or object? However, vision is also an essential motivator. It provides children with the motivation to get moving and explore the world. For example, because they want to see more of the world, babies lift their heads although this is very strenuous at first. They stretch their arms out to try and grab things that they really want to have. And eventually they crawl towards the desired objects. Often, everything they see appears to be so interesting that it just has to be explored and investigated.[5]

Eye contact and joint attention

Eye contact with a reference person is always very important. When children encounter something surprising or unfamiliar during their explorations that makes them feel insecure, they glance questioningly at the reference person (this is known as "social referencing"). For, when exploring the world, children always want to know what other people have to say about the thing that they are investigating and how they deal with it. This ability to engage in joint attention (i.e., to simultaneously incorporate an object and another person into an exchange) develops around the age of eight months and shows that children are interested not only in their environment but also in their reference person's view of the things in their surroundings. Hence, co-construction begins in very early childhood.

[5] Cf. Brawata, I. (2009)

Perception with all our senses

Luckily, information from the environment does not reach us exclusively via our eyes and our vision. Perceiving things with all our senses – in other words, also through taste, smell, hearing, and touch – helps not only visually impaired and blind children to gather and organise detailed information about their environment. Irrespective of the sensory system through which a child takes in the various pieces of information about an object, they are linked and saved as belonging together. For example, a rattler is not perceived either as a thing that can be seen, or heard, or touched, but rather the child immediately relates the various visual, aural, and tactile stimuli to each other. This process is known as "intermodal perception".[6]

Visually impaired and blind children

Because their sense of sight is limited or lacking, visually impaired or blind children develop differently. Vision, motor development, social interaction, and general cognitive development are very closely connected. This can be seen from the different exploration behaviour of the children – that is, the different way in which they engage with their environment and the things that surround them. New and unfamiliar objects practically force themselves upon sighted children because they are in their field of vision. The children then get moving, grab the object, examine it, etc.

At first, blind children have to be helped to perceive that the world is full of interesting things to be explored. One possibility, for example, is to help these children to establish a connection between objects and sounds. In this way, they learn that sounds come from things that can also be touched and used. Moreover, they discover that a thing has not disappeared just because they can no longer touch it, but rather that they can reach it and take hold of it by stretching out their hand or by crawling or walking over to it.[7]

INVESTIGATING THE TOPICS OF LIGHT, COLOURS, AND VISION WITH CHILDREN OF PRE-PRIMARY AND PRIMARY SCHOOL AGE

In order to jointly investigate the topic of light, colours, and vision with children of pre-primary and primary school age, it is important to build on what they already know, assume, and imagine. Only then can they relate their discoveries to their existing knowledge and prior experiences and organise them.

Children's prior experiences and understandings of light

In everyday parlance, illuminated surfaces or the brightness in a room from the sun or a desk lamp are all called "light" by children and adults alike. For physicists, however, brightness and illumination are merely perceptible effects of light. The "light of physics" moves away from a light source at the speed of light. It can be followed only intellectually but cannot be observed directly. The children do not encounter this "imagined light" unless it is explicitly addressed. Many adults also have difficulties imagining light as an invisible, continuous stream. However, that is the central idea on which optics is based.

[6] Cf. Haug-Schnabel, G., Bensel, J. (2004)
[7] Cf. Berk, L. E. (2005); Brawata, I. (2009)

In order to jointly grasp with the children the idea that light is an invisible stream in the air, it is therefore important to deal with the path of light. The first step is to explore lighting effects. Because we take light for granted in our everyday lives, we hardly question the presence or absence of light. It makes sense, therefore, to begin by consciously experiencing and distinguishing the different states of light and darkness with the younger children.

The fact that light travels can be seen when you deal with the topic of light sources and the brightness they generate. Like a stream, the path of light has its origins in a source. Children retrace this path by tracking down the various light sources with the help of the effect of the brightness, for example. When doing so, they check whether every brightness actually leads to a light source.

By deflecting light with mirrors, prisms and other light-scattering objects, the children get to know the complete terminology of light as something that brightens, flows, and is invisible. For example, when the children try to create indirect lighting with the help of mirrors, or to investigate the path of light in a shoe box, they realise that although light is invisible in the air, they are still able to trace and describe its path all the way to the generated light spot. They can therefore predict paths of light and test their predictions.[8]

Children's prior experiences and understandings of vision

Most children know that they need enough light to be able to see well. However, children who live in the city, in particular, do not associate darkness with the complete absence of light but rather with a state in which they can still see something because of the light from street lamps or the illuminated windows of the surrounding houses. Only the experience of complete darkness makes children impressively aware of the fact that vision is impossible without light.

Many adults also find it difficult to grasp the fact that before we can see objects or persons, light emanating from them must enter our eyes. The idea that illuminated objects and persons scatter light themselves, thereby becoming transmitters of light, is hard to accept (for the three concepts of vision, see the figure on the right).

[8] Cf. Murmann, L. (2004), (2010a); Rieck, K. (2010)

A: Light surrounds us with brightness like a bath of light and enables us to see. The connection between the object that is seen and the eyes remains an open question. Almost all children of pre-school and primary school age have this understanding of vision.

B: Light illuminates the object. Vision takes place purposefully with the eyes (idea of "visual rays"): I see something because I direct my gaze to it. Older primary school students develop this idea.

C: Physical explanation: The object must be illuminated. The light is partly absorbed by the object and partly reflected, and this reflected light enters our eyes. Children do not come up with this idea by themselves, and they often reject it.

A good way to approach the phenomenon with the older children is to examine whether the illuminated objects also emit light. If vision is addressed in class, it is important not only to focus on the eyes as an independent sensory organ but also to avoid neglecting the central role played by the brain. Vision does not end at the retina but goes far beyond the eyes.

We see not only what our eyes capture but also what our brain makes of it. Vision has physical, neurobiological, mental, and epistemological aspects. In order to prevent the children from developing two different concepts that stand unconnected side by side (according to the one concept, we direct our gaze at something; according to the other concept, the light enters our eyes), it is important to continuously link the physical and biological aspects of vision in a manner that is clear and meaningful to the children, and to work in an interdisciplinary way.[9]

[9] Cf. Gropengießer, H. (2007); Guesne, E. (1984), (1992); Murmann, L. (2002); Rieck, K. (2010)

Children's prior experiences and understandings of shadows

Many children perceive shadows as their doubles (or "doppelgangers"), similar to their own mirror image. Like the mirror image, their shadow seems to be connected to their own body. However, while we usually see our normal reflection in the mirror, our shadow is sometimes distorted, or enlarged or reduced in size, and we can see only our outline. Despite the effects of distortion, enlargement, or reduction, for younger children at pre-primary level, the realisation that a shadow is a copy of themselves, another person, or an object, is the first step towards concept formation.

"I believe that the sun shines the most and that's why it makes the biggest shadows. The shadow that we made with the flashlight is a bit small; that of the street lamp is a bit medium-sized. The smallest shadow is where there is not much light."

"When the shadow is surrounded by the darkness at night, it is made of darkness. When it is surrounded by light during the day, it is more made of light."

Dealing with this topic playfully by tracing shadows, creating shadow plays, or catching shadows is a suitable way of discovering initial regularities. It also helps to ensure that shadow images lose their frightening character.
In this way, pre-primary children determine whether shadows always move with the object or person, why shadows are sometimes big and sometimes small, and how dark they can actually become. They explore whether shadows also occur in the dark, and they discover, for example, that shadows need two things to form: light and an object that blocks the light. If primary school students have this prior knowledge, they can examine the connection between the two-dimensional shadows they have investigated to date and the three-dimensional shade to which they go in summer to cool off, for example. Even many adults are not aware of the fact that every two-dimensional shadow image is accompanied by a shaded space and that they don't necessarily perceive the boundaries of this space in the air.[10]

"If something is shaking in the wind, the shadow also shakes."

"A shadow is like a film that follows you."

Inclusion of visually impaired or blind children

It may appear doubtful at first whether explorations on the subject of light, colours, and vision can be conducted with children who have visual impairments. However, all children can have simple basic experiences, for example covering first one eye with their hand and then the other eye, or experiencing dark or very brightly lit rooms. Moreover, light effects produced by reflective or refractive objects can be observed on the wall. Spending time in a Snoezelen room (a controlled multisensory environment) with dimmed light sources and colour effects is also very appropriate. Moreover, the experience of total darkness provides an opportunity to discuss the topic of blindness with all the children. In encounters and exchanges with children who are blind, the other children learn how blind people orient themselves and what advantage they have over sighted people in the dark. Together, they can consider what blind people are not able to do and therefore what help they need, and what they can do better than sighted people.[11]

"A shadow is a little piece of darkness."

Child searching for yesterday's shadow on an overcast day: "I'm going to my shadow who's waiting for me beside Mariano."

"It's just like seeing yourself in the mirror except the shadow has nothing on the inside; it's completely black and doesn't laugh."

"The little scientists at our kindergarten conducted a project on the subject of light and colours. They discovered, among other things, that colours are recognisable only if there is light. While they were searching for the colours of the rainbow in nature, the children met a blind woman. That led them to ask lots of questions:
'What does the woman need a stick for?' 'How does the woman know what colour the traffic lights are?' 'How can she pick the clothes that she wants from the wardrobe?' 'How can she pay at the supermarket?' Afterwards, with our help, the children started to look for the answers. The encounter with the blind woman brought a new and unexpected aspect to the whole project.

Report by an early childhood educator at Neige Municipal Kindergarten

[10] *Cf. Murmann, L. (2004), (2010a, b); Reggio Children (2005); all the children's utterances are taken from Reggio Children.*
[11] *Cf. Murmann, L. (2010a); Schröder, J. (2014)*

PROJECT WORK WITH CHILDREN OF PRE-PRIMARY AND PRIMARY SCHOOL AGE

WHAT IS A PROJECT?

Children have lots of questions. They want to explore and understand the world, gain recognition, and communicate. Project work is an excellent way of meeting these needs at early childhood education and care centres, after-school centres, and primary schools. It offers both the children and the teachers and educators diverse opportunities to pursue their interests and use their strengths. Projects enable topics to be addressed on a more long-term basis. They are always embedded in a wider context, they investigate various aspects of a phenomenon, and they cover different educational areas. The word "project" comes from the Latin word *proiectum*, which means "something thrown forth". Hence, projects aim to bring something forward, to move ahead, and to create something new.[12]

Projects enrich everyday life in early childhood education and care centres, after-school centres, and primary schools

Children's self-action and independence are a central feature of projects and project-oriented activities. Ideally, the idea for a project comes directly from the questions asked by the children. However, projects can also be initiated by the facilitators of learning. What is important, however, is that the project topics relate to the children's experiential world. Moreover, it is essential that the children are involved in the planning and implementation of the project and that the things that they experience and discover in the course of the project are jointly discussed on an ongoing basis. When supporting and accompanying the project, teachers and educators should take account of the abilities and the personality of each individual child. The many open-ended situations and questions that arise during a project give each child the opportunity to come up with ideas, and they enable all the children (and the teacher or educator) to experience the challenge of the new and to contribute something to the success of the project in their own individual way.

Children's self-action is at the core of project work

Project-based learning is holistic, true-to-life learning by example. In the course of the project, the children can decide for themselves how, with whom (social form), and how long they want to learn (learning pace), and they can organise their learning individually. The teacher or educator acts as a facilitator and moderator and creates an atmosphere that is conducive to creative ideas. Projects affect very different skills. On the one hand, they are emotional and moving, they arouse joy, fun, and curiosity, and they engender excitement and pride in the children's own learning achievements. On the other hand, they are social because projects are designed and implemented by groups, children and adults have equal rights, and new knowledge is developed collaboratively, co-constructively, and discursively. Moreover, projects have a cognitive impact. They stimulate the minds of all participants and help them to understand the world.

Holistic learning in projects

In contrast to open-ended, project-oriented activities, projects always have a concrete objective with a beginning and an end. In the context of the topic of light and shadow, for example, children engage in project-oriented activities when they investigate the properties of shadows and examine how a shadow occurs, and how it changes its direction, length, and size. These activities differ from a concrete objective to stage a shadow play of your own, for example, which would be classified as a project, and which shows clearly that projects are something special and unique that sometimes even leave behind a changed reality or something new. When staging a shadow play, it is also necessary to address the properties of shadows in order, for example, to make a giant appear on the screen beside a dwarf. However, in this case, learning about shadows and their properties is just one step on the way to staging your own shadow play.

Projects and project-oriented activities

[12] *Cf. Katz, L. G., Chard, S. C. (2000); Jacobs, D. (2012)*

HOW DOES A PROJECT PROCEED?

Phase 1: Finding a topic

The key to the success of a project is to find a topic that interests all the children, if possible, and that motivates them to engage in inquiry. There are many ways in which exciting project topics can emerge. What are the children working on at the moment, individually or with others? What activities are they engaged in? Have they voiced specific interests, questions, ideas, or observations?

Topics can be prompted by:

- *Observing that children are interested in particular topics*
- *Questions that the children ask*
- *Topics close to the children's hearts*
- *Situations/occurrences and phenomena that attract the children's interest, and utterances that the children make on the basis of observations ("How do rainbows form?" "Can we make one ourselves?")*
- *Problems that have to be solved ("How can we integrate the new, visually handicapped girl into our group?" "How should the new garden be laid out?"*
- *Conversations among the children themselves and/or between the children and the teacher or educator*
- *Stimulating things that are brought into the institution*
- *Forthcoming celebrations*

"In a pleasant, relaxing atmosphere with [...] music, the children went on a mental journey. We call this daydreaming method, which leads the children to their favourite topics, 'television in your head' [...].

The children recounted all the things that they had seen and experienced. They saw themselves as knights and heroes, they talked of knights' castles, gold, precious stones, jewellery. [... Later] the children drew pictures of their topics, which we hung up for a week. During the week, the children were able to engage with the pictures and prepare for the children's conference at which the joint topic for the project was to be found." [13]

Once the topic has been found, sit down with the children and discuss whether anyone already knows anything about it and can tell the others what they know. This yields a small collection of topics for the project planning phase, and the children experience that people can think and know different things about one and the same topic. Jointly consider what other information will be needed and whether an expert should be consulted or can help (for example, the local baker, who knows more about the topic of "making bread rolls" than all the members of the group).

In your team, you can reflect on whether the topic is suitable for all the children and whether it covers several education areas – that is, whether it fosters not only cognitive skills but also social, motor, and emotional skills, for example. In addition, you should check whether the topic suits the respective environment/setting and whether the necessary supporters can be recruited.

[13] *Mai, I. (2006), p. 51 f.*

Phase 2: Planning and preparation

The project plan is drawn up with the children. It sets out the introductory steps, the tasks that will arise, and how they will be shared out. For example, who will take care of the material, and what rooms will be needed?

It is important to note that the plan should be flexible. It would actually be better to call it a project draft because the whole endeavour – that is, the path that the project will take, led by the children's thirst for knowledge – can never be conclusively planned. Hence, the structure and planning are not in the foreground. Rather they form the scaffolding for the implementation of the project. If the project plan is hung up for all to see, the children can frequently look at, and proceed with, the individual project steps or change them in consultation with the other participants. In this way, they are actively involved in the project from the very beginning and they learn to collaborate with others.

Questions addressed during this phase include, for example:

- *What question or problem is to be solved? How can the resulting tasks be described in concrete terms?*
- *Who will take on which task?*
- *What are the first steps?*
- *What things and rooms are needed or are prescribed?*
- *What help can I offer as a teacher or educator? What information or support do I need?*

Phase 3: Implementation

Depending on the topic, you can organise the implementation of the project in very different ways. For example, the project may relate to a question about the natural environment that is addressed by means of inquiry activities and visits to the museum. Or it may be a practical project devoted to building or constructing something. In the latter case, handicraft enterprises can be of help. Besides everyday topics, for example, buying and preparing food, you could investigate topics such as the weather, the seasons, or outer space by undertaking excursions and observations and using media and visual aids. Anything is possible!

Generally speaking, we recommend: Less is more! Project work is not about conducting lots of different inquiry activities, one after the other (even if they are all of relevance to the topic). Rather, it is a question of examining a question in depth. It is better to start small and bring the children's various discoveries and investigations together well and to acknowledge and document them appropriately.

Besides group activities, the children need enough freedom to individually explore and process aspects of the topic. Moreover, they have a different concept of time than adults, and they often take steps that adults would skip. However, these apparent detours are just as valuable as the actual objective. As a teacher or educator, you should try to maintain a low profile and to give the children the space they need to find their own rhythm. It is important to find a good balance between giving prompts and suggestions on the one hand and exercising restraint on the other.

The project plan or "talking walls" can document the course of the project on an ongoing basis. Another idea is to provide each child with a personal project box to which they always have access in order to show grown-ups or other children what they are working on at the moment and to engage in conversation about it.

A project always includes

- *the children's own questions and ideas,*
- *phases of inquiry-based learning,*
- *phases of collaborative learning in groups,*
- *phases of teaching and being taught (co-construction),*
- *situations of interaction and exchange, and*
- *situations of bafflement and brainstorming.*[14]

[14] *Cf. Jacobs, D. (2012)*

"One boy brought in a poster from the Star Wars series, and the children were particularly enthusiastic about the Jedi knights' lightsabers. Whenever they found a stick, it turned into a lightsaber. Trading cards and albums from the series did the rounds; the children swapped [stuff], cut things out, and did drawings. Then [I] thought to myself: If you want to take the children seriously, you've got to take up the Jedi knights [topic]. But what will the parents think of it? [...] The children are just playing Star Wars non-stop. I don't know [...] Whenever a project begins, [I] always ask: What do we already know about the topic? [... I didn't know anything myself, which is good because that way I couldn't specify anything.] It turned out that even the boys didn't know as much as they seemed to [...] What actually happened in the story? 'No idea.' 'Where does the story take place?' 'In the galaxy, of course!' 'Aha.' One child said: 'I have a film about the galaxy.' [...] The next week we had a film show every day – namely, the [children's] film about space travel, planets and the Milky Way [...], that's how the project began. [...] Colours, wood, and clay are always available to the children in the art studio and the workshop, so that [in addition to a lot of space ships] the children produced lots of portraits and sculptures of Master Yoda. 'Yoda radiates the good power," one child said while he worked. 'What does "radiate" mean?' [... I asked]. Someone replied: 'The sun radiates.' 'The flashlight does as well,' said another child. 'What power [do you mean], anyway?' 'The power of love, of course!' 'And how can you tell that?' 'From his eyes or his mouth when he laughs.'

A guessing game began. Somebody acted out an emotional state and the other children had to guess what it was: happiness, sadness, bravery, fear ... The children also built planets [...]. In the end there were so many of them that a three-dimensional solar system was created [...] And of course there had to be proper lightsabers [...] The children brought materials from home. We tested them to see whether they were suitable. In the end, plastic tubes turned out to be suitable [...] Little flashlights were stuck into one end so that they really shone. [They tried them out] in the light and shadow room. One child called out: 'Frau Förster, come quickly!' [... I] came and saw: Lots of galaxies spread out across the dark wall, produced by the beams of light that were bundled in the tubes and hit the wall. That was a surprise! [...]" [15]

Phase 4: Conclusion

The conclusion of a project not only means that the project results are presented. It also offers the children an opportunity to celebrate their many small successes, to receive appreciation and recognition for their efforts, and to develop a desire for further knowledge. The evaluation of the project with your team, with parents, and with supporters also contributes to the successful conclusion of a project.

Possible questions for the conclusion of a project:

- *What did you find fun? What new things did you learn? How, and with whom did you learn them?*
- *How did I/you as a supporter or a parent like the topic?*
- *What impact did it have on the group/on me/on the children?*
- *What went well? What did not go well? What did I do well in my role as a facilitator of learning?*
- *What content from the education programme or the framework curriculum/education curriculum was addressed?*
- *How was cooperation organised (and with which cooperation partners) and what have I learned from this?*

[15] *Das Gute muss siegen [Good must win out] (2013).*

Project work gives the children the feeling that they themselves and their questions and interests are taken seriously. They learn to formulate their questions and interests, experience that learning is fun, and that it is worthwhile engaging in inquiry and getting to the bottom of things. And what do teachers and educators gain from it? They acquire additional professional skills and recognition for their work, and they become learners who ask questions about the natural world and achieve new knowledge.

PROJECT WORK AND THE PEDAGOGIC PRINCIPLES OF THE "HAUS DER KLEINEN FORSCHER" FOUNDATION

Project work supports co-constructive learning

Co-constructive togetherness, dialogue between all participants in the process of inquiry, and supporting children in the development of metacognitive skills are at the heart of the pedagogic approach of the "Haus der kleinen Forscher" Foundation.[16]
Project work enables children to engage in holistic, true-to-life, and exemplary learning about a jointly chosen topic, thereby enhancing their joy of inquiry and understanding. The approach taken in project work enables the children to determine themselves the method, pace, and social form of their learning (how, with whom, and how long) and to organise it individually. Children and adults, and the children among themselves, form a learning community and contribute their ideas, suggestions, and explanations to the project. In this way, they learn from and with each other.

Project work promotes dialogue and strengthens cognitive and personal skills

Project work offers many opportunities for dialogue between teachers or educators and children. The teachers and educators engage in reflection with the children and encourage them to formulate and record their observations. By jointly discussing their observations and experiences, connections between things become clear to the children; they visualise learning content and their learning process; and they talk about what and how they are learning. Moreover, they discover what it means to exchange ideas and engage with others. Within the framework of the project, they leave familiar terrain, master unfamiliar things, deal with frustration (when something does not go as planned or fails), and learn to handle conflicts and problems. This not only enhances their competence, it also gives them a lot of self-confidence and strengthens the feeling that they have independently achieved something ("Yes, I can!").

Using projects to obtain certification as a "Little Scientists' House"

Show parents, partners, and colleagues how enjoyable exploration and inquiry can be. Use your documented projects on scientific, mathematical, or technical topics to have your institution certified as a "Haus der kleinen Forscher" (Little Scientists' House).
You can find information about the certification process on our website **www.haus-der-kleinen-forscher.de** and in the brochure *Wir lassen die Neugier in Kindern aufblühen* (We allow children's curiosity to flourish).

[16] *Cf. also the brochure Pedagogic Approach of the "Haus der kleinen Forscher" Foundation.*

SUGGESTIONS FOR PEDAGOGIC PRACTICE

In the following chapter, we present real-life projects and supplement them with numerous ideas on the respective topics. The chapter features thematic sections on light and life, the sun, natural colours, night, and optical technologies.

Please use the ideas to investigate these topics with the children. However, you should regard these ideas as recommendations and decide for yourself which of them are suitable for a project under the conditions prevailing in your institution. When doing so, involve the children. Take into consideration their experiential background and their questions and interests in relation to the topic. Have the children participate in the planning and implementation of the project and explore individual questions in depth rather than trying to engage in as many activities as possible.

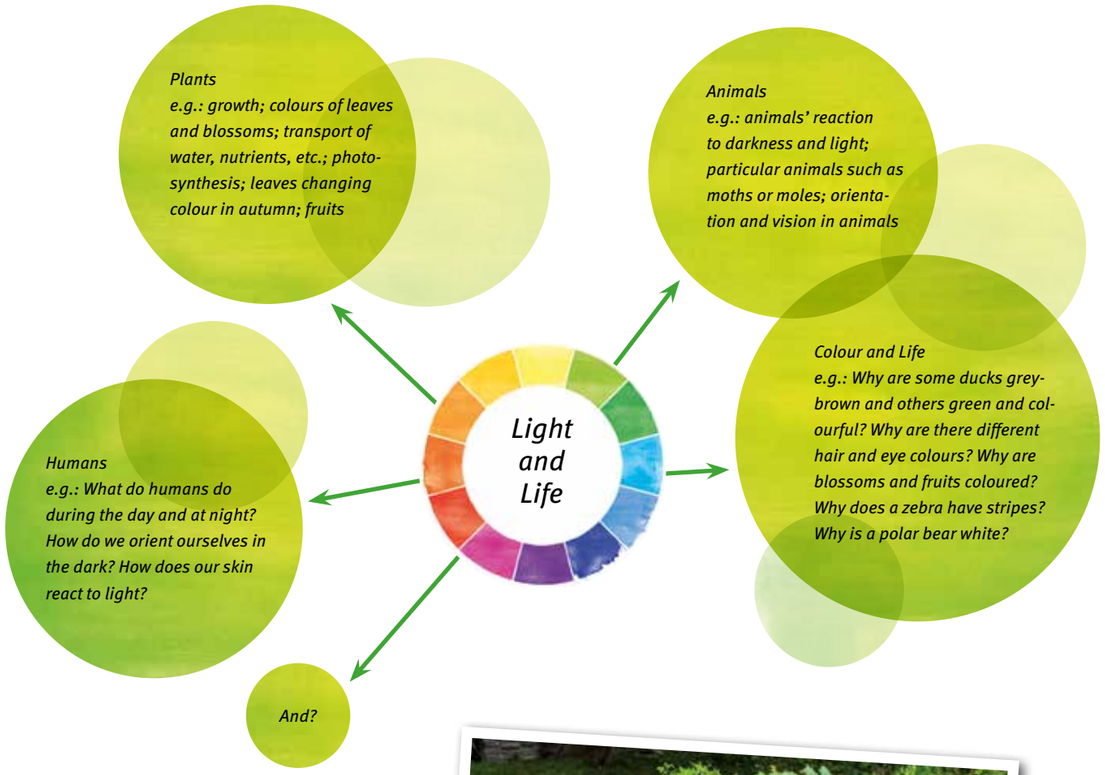
You will find notes in the margin whenever there are substantive links with the set of cards for teachers and educators entitled “Light, Colours, Vision – Exploring Optics” or with the exploration cards for children. Please also make use of the suggestions, ideas, and inquiry activities presented on these cards.

Accompanying sets of cards

LIGHT AND LIFE

Sunlight is the basis of all life on earth. The sun is our omnipresent light source and it influences the lives of plants, animals, and humans. Plants can use light energy to produce new biomass; they are eaten by animals. Moreover, light influences the biorhythm of animals and plants, for example via the length of day and night. Light enables different colours to be perceived. Animals and plants use colours to camouflage themselves or to give warning signals. Brightly coloured fruits and blossoms attract animals so that they can disperse the seeds of the plants, for example. Light has many other effects on plants, animals, and humans. Set off on an expedition with the children to explore the topic of “Light and Life”.

What experiences have the children had with light so far? When do they find it too bright or too dark? What light is pleasant? Where does light come from? When we're out walking in the dark, we prefer to take a lighted path. Other animals avoid the light. Have the children also observed such an affinity with, or aversion to, light in plants? What questions do the children wish to pursue. The following sections show ways in which you and the children can jointly investigate the influence of light on living organisms in our world. A project that addresses this topic can go in many different directions:



A certified institution (St. Agnes Catholic Kindergarten in Zülpich-Lövenich) reports:
We built a raised bed and investigated plant growth:

"Within the framework of our topic of the year 'Fit and healthy through the kindergarten year' and on the basis of various observations, we opted for the project 'We're building a raised bed' as we had observed that the children had an increased interest in plant growth and in the question: 'Where does our food come from?' In individual project steps, we explored the living and environmental conditions that plants need and the fundamental importance of plants for our planet. In the children's conference, we take the children's interests into account.

In the weeks that followed, we built a raised bed, planted different vegetables, and observed their growth. Almost every day, the children observed the changes in the raised bed. We also filled a showcase with different layers of soil, collected earthworms, and observed the changes in the showcase for a week. What do earth worms do with the soil? After the first week, we planted radish seeds in the showcase and observed how the seeds germinated and the plant formed roots."

LIGHT AND PLANTS

Plants need light

Set off on an expedition with the children in and around your institution to explore the topic of "Light and Plants". Early blossoming plants, for example, grow very fast towards the spring sun. Depending on the position of the sun, sunflowers turn their heads in its direction; within just a few days, the leaves of indoor plants turn towards the light. Why do plants grow upwards or turn towards the light? Why are leaves green? What do plants need to live?
What happens to a plant if it gets no light? How much light do the various plants need?
What do plants in sunny places or in dark shady places look like?

More knowledge

Plants produce sugar for their growth and their energy metabolism. They are able to bind carbon dioxide from the air and to convert it into sugar and oxygen with the help of light energy and water. This process is called photosynthesis. It takes place in the small, green organelles of the plant cells: the chloroplasts. In these "power stations," the plant pigment chlorophyll absorbs all the colour components of light except green. This gives plants their green colour.

To find out, for example, what place in the group room is the most suitable location for a plant, you could conduct an inquiry activity to compare plants in the dark and in the light. The children line two small plastic trays with moist paper towels and scatter cress seeds over the paper towels. They put one tray in a place where it gets lots of light, for example on the window sill, and they put the other tray in a dark place, for example a windowless cupboard. Check the trays regularly with the children and document growth progress with photos or drawings.

Greenhouse cultivation

The sun is a source of heat. In summer, rooms heat up when the sun shines in through the windows. Discuss with the children their experiences with the warmth that the sunlight provides. For example, some children know what it's like to get into an overheated car in a car park. In greenhouses, we make use of this effect. Most plants flourish best in warm locations that get lots of light. Greenhouses consist mainly of glass. Therefore the plants get a particularly large amount of light and heat. The children can very easily investigate the greenhouse effect themselves. To do so, they will need a large preserve or storage jar, which they place upside down over a patch of grass on the lawn. To make sure that air can still get in, have the children place a little stick under the rim of the jar. In the days that follow, observe together the growth of the grass under and outside the jar. Does one patch grow faster than the other?

More knowledge

The transparent glass allows the sunlight to enter the preserve jar. When the incoming short-wave solar radiation hits the patch of grass underneath, it is converted into heat and reflected back towards the sky in the form of long-wave thermal radiation. However, the glass does not allow the long-wave light that is reflected by the ground to escape as well from the jar. Therefore it soon gets very warm inside the glass. This phenomenon is known as the greenhouse effect. It is very easy to build your own small greenhouses for your group room. All you need are empty drink cartons and yoghurt pots, bubble wrap, and aluminium foil.

The children can start various projects in the raised bed, the garden, or the greenhouse. Spring – and especially the month of March – is a very good time to grow herbs, for example. Encourage the children to document the growth of the plants. Ask them how they wish to do this.

For example, they could use pieces of string to measure the distance between the root and the tip of the plant, and they could hang up the pieces of string beside each other each day. Older children could measure the lengths of the pieces of string with a ruler and illustrate the growth curve by using the diagram generator on the children's website www.meine-forscherwelt.de.

Chlorophyll

How do the leaves on the trees change during the year? What do the children notice? Jointly collect leaves from different trees in spring, summer, and autumn and discuss the colours of the leaves and the way they change in the individual seasons. What could these changes mean? What questions are of interest to the children? Why are leaves green? Why do they become colourful in autumn and then fall off the trees? How do plants use light? What happens when a leaf does not get any light?

More knowledge

When the number of hours of sunshine decreases in autumn, the chlorophyll in the leaves is broken down. As a result, the other pigments in the leaves, which have been concealed by the chlorophyll up to now, emerge. The leaves turn yellow and red. Because the leaves cannot produce any more food, they no longer need the plant and they fall off.

The children can easily investigate the effect of light on leaves. To do so, they cut out two leaf shapes from a sheet of black craft paper. The paper leaves should be big enough to completely cover each side of the leaf of an indoor plant. Then the children use adhesive tape to carefully affix the paper leaves to the front and back of the leaf of the plant in such a way that it is no longer visible. After a week, the children can remove the craft paper. The leaf will have turned pale and yellow.

Experiment with different lengths of covering time, or cover only one side of the leaf. The children can conduct the same covering and uncovering activities with fruit – for example with apples ripening on a tree.

LIGHT AND ANIMALS

Light is also vital to animal and human life. Consider with the children the situations in which animals and humans need light. Light enables us to see and to perceive colours. Moreover, sunlight stimulates the production of vitamin D in the skin, for example. Vitamin D influences bone density and mood. That is why we feel happy when the sun shines.

Life in the dark

There are animals that live in darkness, for example underground. How do animals orient themselves without a light source? Talk to the children about their ideas about life in darkness. What animals do the children know that are active in the dark, for example at night? Perhaps some of the children have pets that are nocturnal – for example hamsters. What possibilities are there of finding your way in the dark? Have the children try walking a certain route with their eyes closed. Jointly agree on a start and a finish point in the group room or even outside in the playground.

What other ways are there to find your way, apart from carefully touching things with your hands? Have the children line up on two sides facing each other and humming softly. One of the children closes his/her eyes and walks down the “humming lane”. He/she uses the sound of the voices to orient him/herself, thereby finding the way. The other children can help the child in the humming lane by humming louder or more softly to indicate the direction.

Reflectors – with glowing eyes

Do the children know any animals that can find their way well in the dark? Owls are not the only animals that hunt in the dark. Cats do so, too. They can see and orient themselves excellently in the dark. Have any of the children ever seen the eyes of a cat glowing in the dark? How does this glowing actually work?

More knowledge

Cats’ eyes have a reflective pigment layer – the tapetum lucidum (Latin: “bright carpet”). The light that enters the cat’s eye is reflected back by this layer. In this way, it reaches the retina twice. As a result, the photosensitive cells in the eye are hit twice so that perfect use is made of the little light there is. We perceive this reflection as a glow in the cat’s eyes.

The children are familiar with the glowing of cats’ eyes from the reflectors on their bicycles, jackets, or rucksacks. Jointly investigate the effect of these reflectors. To do so, the children take photos of each other in different situations. Some put their jackets and their rucksacks on and others stay in normal clothes. The children take photos of each other in the light and in the dark with or without illumination or with a flash – the strongest type of illumination. In what situations can the children be seen clearly? In what situations are they difficult to see?

Camouflaging and warning

Consider with the children why animals that live in the forest usually have a brown or reddish coat. Discuss the fact that animals use their coats or plumage for the purpose of camouflage or adornment. Jointly collect pictures of animals from magazines and brochures. Have the children make collages and draw pictures in which the animals use their coloration to camouflage themselves in their surroundings – for example, a brightly coloured butterfly on a brightly coloured blossom, a tree frog in a meadow, or a deer in the undergrowth.

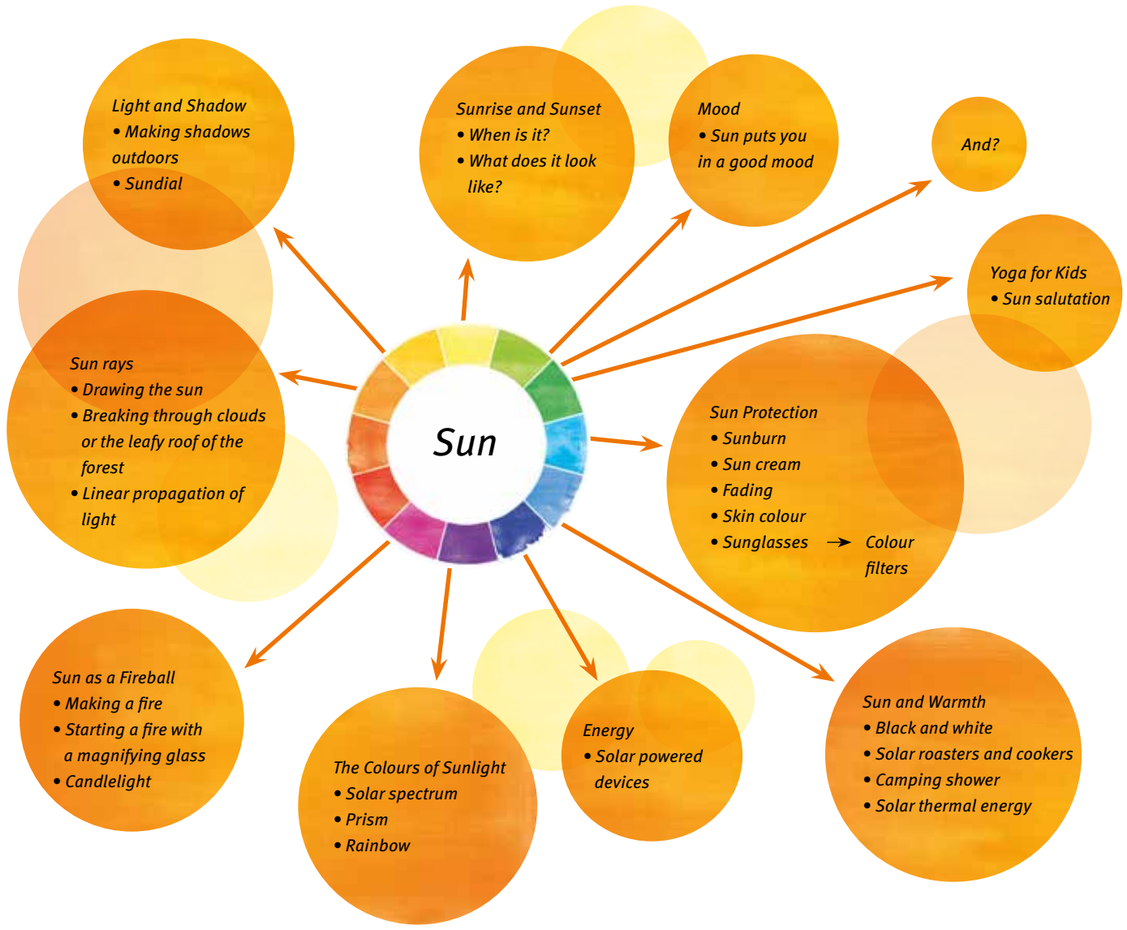
Consider with the children the best way to camouflage themselves. Where do they want to hide? What colours are there in that place? What do they have to wear in order not to be seen in a particular place? In traffic, on the other hand, it is important to be seen clearly. Talk to the children about signal colours. What colours are good warning colours? In what situations do people wear a warning vest?

Pool the results at a joint conference

What influence does light have on our lives, on animals and humans? Encourage the children to present their results within the framework of a conference. Consider together how you wish to use the insights gained. For example, you could reorganise your system of plant care. Certain children assume responsibility for plants, look for a suitable location for them, and take care of the watering. The herbs that are grown could then be used by all the children at breakfast or for cooking. As a result of the activities relating to camouflage and warning, the signage in the institution could be examined, for example, and safety ideas could be collected. The results could be recorded on a poster.

SUMMER, SUN, SUNBURN

The sun is our source of life on Earth. Without it, the Earth would be nothing more than an ice-covered lump of rock in complete darkness. In summer, we feel the power of the sun particularly strongly. What does the hot sun do to us or to our institution building? How does the sun change the landscape in summer? How does sunlight actually come about and why is it so strong that we even have to protect ourselves against it? A sun project can go in many different directions:



In summer, St. Michael Catholic Early Childhood Education and Care Centre in Neuss availed of the opportunity to conduct a project on the subject of “The Sun, an Inexhaustible Source of Energy”. After the children experienced the warmth of the sun on their skin on a warm and sunny day, they shared the experiences they had had with the sun and developed their own questions.

A certified institution (the St. Michael Early Childhood Education and Care Centre in Neuss) reports:

"After finding the topic, we looked at the positive sides of the sun as it is our main source of energy. It gives us light, power, energy, and warmth; it makes us happy; it causes plants to grow. But the sun also has its downsides. It is pure energy, and when it is unfiltered it can destroy life. The skin and the eyes must be protected from too much sun. In many discussions and in the course of inquiry activities, we found answers to lots of questions: What makes me happy on a sunny day, and what do I do when the sun shines? How can I perceive it with all my senses? What is the sun and what does it look like? Do animals and plants need the sun? How do we protect ourselves from the sun? And how do we humans use its light and warmth?
With the help of the project I was able allay the fears of the children and their parents about the sun and also convey an awareness of how to deal with sunlight and of the protection that is needed. Four major milestones accompanied us during the project and gave it the necessary structure:

1. *I am happy when the sun shines: Perceiving and describing the sun, its brightness and warmth and how one feels in the sun and without the sun.*
2. *Sun is life: Explorations in nature. What would happen if the sun did not exist?*
3. *The sun gives energy: Investigating interconnections, for example that the sun dries the washing and that solar energy can be used in self-built solar cars and helicopters.*
4. *Caution: Sun! Raising awareness of sensible sun behaviour and sun protection."*

Sunrise and sunset

The sun shines and brings us light and warmth. We notice it particularly when it shines brightly or when it rises in the morning and sets in the evening with an impressive play of colours. Have the children ever seen the sun rising or setting? Can they remember a particularly beautiful sunrise or sunset? Have them describe what it looked like and what mood they were in when they experienced it. Encourage the children to draw a sunrise or a sunset. If possible, watch a sunrise or sunset with them.
Jointly consider what location (e.g., a hill or a tall building) would be a good place to observe one. Children, and even many adults, have the idea that the sun goes down. This is also anchored in our language in the words sunrise and sunset. However, it is the Earth that turns away from the sun. Like the other eight planets of the solar system, the Earth rotates on its own axis and revolves around the sun. When the Earth turns away from the sun, it appears to us as if the sun is going down.

Caution! Point out to the children that they must never look directly at the sun during the day. This can permanently damage the sensory cells in the eye.

More knowledge

Viewed from outer space, the sun looks white. However, it usually appears yellow to us. Its yellow colour is due to the influence of the Earth's atmosphere. The particles in the atmosphere (they can be air and dust particles, soot, droplets of sulphuric acid, pollen, or bacteria) scatter the sunlight in different directions. Blue light is scattered much more strongly than red, which is why the sky appears blue to us and the sun does not look white but rather yellow. The colours of the sky at sunrise and sunset occur because the light of the low-lying sun travels a longer path through the atmosphere to reach us. On this journey, more blue light gets lost through scattering and the sun takes on a reddish hue.

Do any of the children in the group know when the sun rises at the moment – when everyone is still asleep, shortly before the morning circle begins at kindergarten or lessons begin at school, or even later? Does the sun always rise at the same time? Start observations over an extended period of time. Each day, one child is given the task of making a note of when it gets bright and when it gets dark. Agree on criteria for this. Can the children already say after a week whether the days are getting shorter or longer? Conduct further research on the sun's path over the course of the year.

Sundial

After you have addressed the topic of sunrise and sunset with the children, you can now examine the sun's path over the course of the day. Consider together how you could build a sundial. Encourage the children to look up books or the Internet and to ask their parents.
Listen to all the ideas proposed in the group and jointly discuss how you should proceed. For example, every hour on the hour in the mornings the children could stick an approximately one-metre-long stick vertically into the ground or the sand in a sunny place.
Choose a place that it is in the sun during the entire observation period. Every hour on the hour, the children examine the shadow of the stick and mark its location by placing little stones on the ground. In this way, the "clock face" arises. What do the children find out? In what direction does the shadow wander in the circle? How long are the individual distances? What could be the reason for this? Do the positions change the next day?

Investigate further with the exploration card for teachers and educators entitled "Shadows change"

More knowledge

Before the mechanical clock was invented, the sundial was the most important timepiece. The ancient Egyptians, Greeks and Romans used sundials to divide the day into smaller units of time.

The colour of sunlight

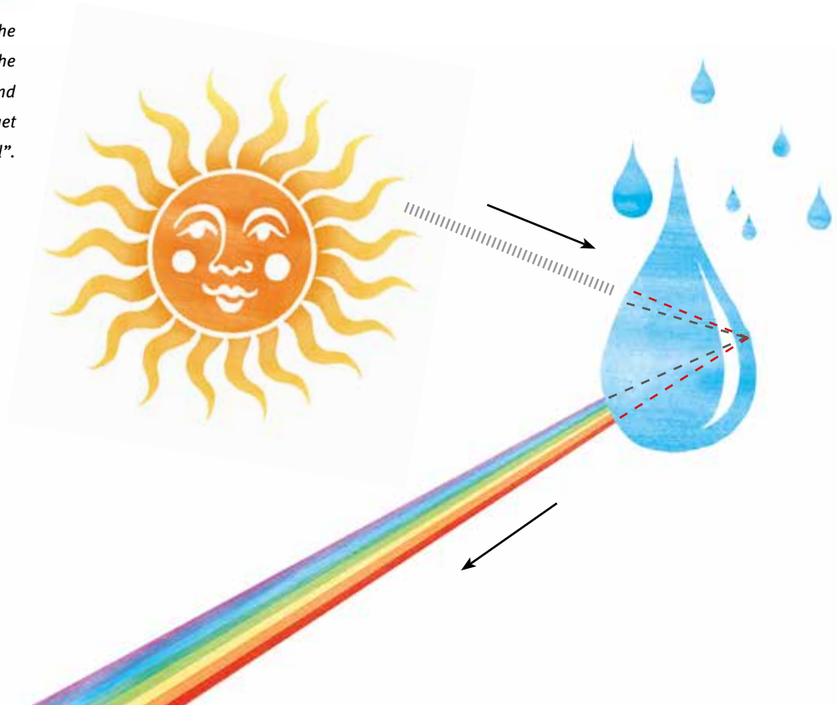
After the children have investigated the path of the sun, it is appropriate to take a closer look at the light that the sun sends to us.

Jointly look at the visible colours that sunlight contains. Use a prism or CDs to split light up into its component colours. Look at the brightly coloured light behind the prism. CDs also split light into brightly coloured stripes. What do the colours look like? What order are they in? Ask the children whether they have ever encountered such brightly coloured stripes.

Make your own rainbow

Talk to the children about the rainbow: Who has seen one recently? Who likes to draw rainbows? What colours do you need? What meaning do rainbows have in fairytales and stories? What do the children believe in? On a sunny day, go outdoors with the children and create a rainbow with water from a garden hose or a sprinkler. Give the children lots of time to try out how they must hold the hose in order to see the rainbow.

Investigate further by using the "disco lights" idea on the exploration card for teachers and educators "Now things get colourful".



More knowledge

White (sun)light consists of the colours red, orange, yellow, green, blue, and violet. When white light enters a water droplet or a prism, it is refracted and split into its component parts. Because the colours have different properties, some are refracted more than others. For example, blue light is refracted more than red light. When the refracted light leaves the raindrop, it is refracted once again and spreads out into its component colours even more.

So the sun sends us light in which many colours are hidden. The sun brings us warmth, and it puts us in a good mood. However, it can also be dangerous. Did the children ever have sunburn?

Sun protection

Sunlight also contains ultraviolet radiation that is invisible to the human eye. This radiation can damage our cells and cause sunburn or even skin cancer. However, solar radiation is not only dangerous for humans. It also causes paint to crack, plexiglass to become brittle, and colours to fade.

Can the children perhaps find things beside the windows of your institution that have been faded by the sun? Perhaps a craft paper picture has been hanging in the window of your group room for some time. Jointly compare the colours of the craft paper with the same or new craft paper from the drawer. What do the colours look like? Is one lighter than the other?

Investigate further with our pedagogical resources on the subject of "Strom und Energie" (Electricity and Energy).

The ideas provided here show how you can handle the optical aspects of the "sun" topic with the children. Of course, you can examine many other aspects of the topic, for example solar energy. You will find numerous ideas from practice on this aspect in our thematic brochure *Strom und Energie* (Electricity and Energy). You can also transfer the inquiry activities to other education areas. For example, yoga, works of art, and songs can be used to experience the topic holistically.

Celebrate successes and throw a party for the sun.

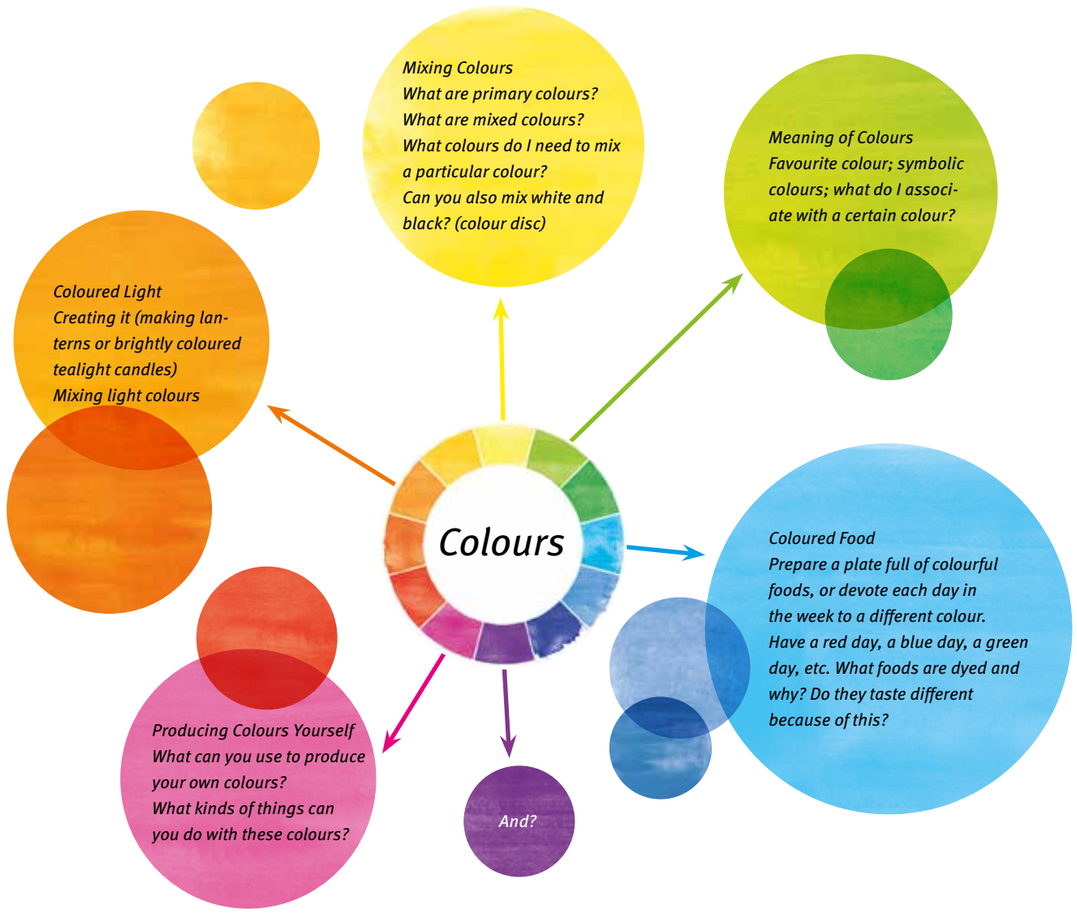
At the end of the project, organise a sun party with the children. In this way, you can celebrate the little and big successes and findings and present the project results. What ideas do the children have for their party. What decorations suit the sun? Do the children know any songs about the sun that they could sing? What drinks would be suitable for the party (e.g., yellow orange juice made from sun-ripened oranges)? What should there be to eat? In what way should the results of the inquiry activities be presented? Should the guests also replicate some of the inquiry activities themselves?

COLOURS FROM NATURE

You can find further ideas on the exploration cards "Now things get colourful," "Does everything end up brown?" and "Can brown become colourful again?".

Colours are ubiquitous. They are also an exciting topic that offers many opportunities for inquiry activities. To introduce the children to the topic, you could take them on a "colour hunt": What things are green? How many yellow things are there in the group room? What colour are the things that surround the children? Can all the toys be sorted according to their colour?

Organise a "colours week": Everyone spends the first day in red clothes, the second day in blue clothes, the third day in yellow clothes, etc. On such a "colour day," the children paint, make things, and sing about that day's colour. They talk to each other about things that are the colour of the day, and they eat only things of that colour. For example, they eat only red things on the red day. In addition, special activities can be organised (red: visit to the local fire station; blue: excursion to the swimming pool, etc.). When you address colours with the children in this way, a project will quickly develop. And because the topic is so diverse, the project can go in very different directions. For example:



In Zwergennest Early Childhood Education and Care Centre, an entire natural colours project grew out of an idea proposed during the morning circle. The children worked on the project for weeks.

A certified institution (Zwergennest in Hüllhorst) reports:
How much colour is there in elderberry juice?

"In the autumn, I brought elderberries to the morning circle and suggested to the children that we make elderberry juice out of them. I said to them: 'But we'll have to wear aprons because the juice from elderberries is a colourant and if you get it on your jeans or your pullover you won't be able to wash the colour out.' When I said that, the children noticed that the word "colourant" contained the word "colour". They were interested in finding out how we could get the colour out of the elderberries and whether this colour was also suitable for painting. We tried it out.

The children were actively involved in every work step required to produce the elderberry juice. They experienced it with all their senses: 'Hmm, elderberry juice smells good!' 'When I mash the elderberries with the fork, the colour really splatters!' Depending on the way the light fell on the elderberry juice and how concentrated the colour was, it looked very different: 'Mine is blue and yours is purple!' 'But on your mouth the elderberry colour is pink!' 'But in my cup the colour is black!' Four children with four different statements about the colour of the elderberries. Later, the children tested the elderberry juice on different types of paper and dyed sheep's wool with it. They enjoyed experimenting with elderberry juice so much that we also used other materials such as red cabbage and curcuma to colour things.

One of the children brought in beetroot juice – the previous day the family had had beetroot for dinner, and now the child wanted to try out whether beetroot juice was also a colourant. Another day, the children and I cut the dried blossoms off our geraniums. When we looked at our hands afterwards, we noticed that they were all red. The children said: 'That's the same as with the elderberries!' So we picked more blossoms and the children started to paint with them."

Painting and colouring with plants and fruits

Making your own natural colours, e.g., from ...
- *grass*
- *elderberries*
- *dandelion juice*
- *dandelion flowers*
- *St. John's wort*

... from the garden or the vegetable shop:
- *blackberries, raspberries,*
- *blueberries, cherries*
- *blackcurrants*
- *red cabbage (cut into small pieces)*
- *spinach*
- *red bell peppers (grated)*
- *parsley (crushed)*

... from the kitchen shelf
- *black tea or coffee for brown shades*
- *various spices, e.g., curcuma or paprika*

Caution: Not all plants are suitable for the production of natural colours. Frequently found plants such as common ivy, yew, foxglove, angels' trumpet (Brugmansia), rhododendron, and deadly nightshade (Atropa belladonna) are poisonous. Before you collect plants and reduce them to small pieces, find out whether there are any poisonous plants in the vicinity of your institution. [17]

When experimenting with plant juices as colourants, it is advisable to use blueberries (also canned or jarred), (fresh) beetroot, red cabbage, raspberries, or redcurrants. To get the juice for painting out of the berries, mash them carefully in a bowl with a spoon or a fork.
If the children cut beetroot or red cabbage, they are likely to have coloured fingers afterwards. They can press their fingers on a piece of paper to make fingerprints. Both vegetables can also be boiled down in a little water. The resulting liquor has a very intense colour and is a very strong colourant. How about colouring Easter eggs with the children? Or dyeing fabric? Particularly beautiful effects can be achieved when the children use the fruit or vegetable juices to paint on watercolour paper.

In every season, different colours or shades can be found in nature. Set off with the children in search of blossoms, fruits, leaves, grasses, etc. Jointly try out whether the plants and blossoms you found leave coloured traces on a sheet of white paper. (Caution! Some plants are poisonous, so please note the list of recommended plants.) In many cases, the plant parts have to be reduced to small pieces first. There are different ways of doing this, for example tearing, cutting, mashing, grinding, or squeezing. The children can try out different methods. The cell sap that exudes from the plants contains colourants and, like the fruit juice in the previous example, it can be used to paint on paper.

Beetroot or blueberry juice are very suitable for dyeing fabric. The children will need prewashed pieces of (non-impregnated) fabric, which they place in a bowl filled with the juice in question. When dyeing the fabric, vinegar essence or a fixative agent can be used (two tablespoons per litre of juice). In this way, the colours stick better to the fabric fibres and do not wash out as quickly. However, as a general rule, the dyed fabrics should be washed separately from other laundry.

[17] *A more comprehensive list of common poisonous plants can be found on the German-language website www.erste-hilfe-fuer-kinder.de/Giftpflanzen/giftpflanzen.html Many English-language lists can be found on the Internet.*

Cave paintings made with earth, chalk, charcoal, and soot

Since prehistoric times, ground charcoal or "burnt" or "unburnt" earth have served as colour pigments. With the children, collect loam, clay, earth, or stones in as many different colours as possible. Can you draw with them straight away? To find this out, jointly choose different surfaces, for example paper, stone, or asphalt. Does the colour of a pebble correspond to the colour of the line drawn with it on the surface in question? You will discover that no matter what colour a pebble is, the line you draw is usually white. This white line is made up of fine dust, which is either rubbed off the pebble or the surface while drawing.

To obtain colour pigments, the children grind the dried and sieved earth, chalk, plaster of Paris, loam, clay, brick, or sandstone finely with a pestle and mortar. Instead of a pestle and mortar, they can also use a stone or a hammer on a hard surface. Big pieces of earth or stone can be put into a small plastic bag before grinding and beaten with a hammer. To ensure that the colour pigments adhere well to the surface on which you are painting, you should mix them with a solvent and a binder. This makes them into durable artist's colours, which can be kept well in a sealed jar.

Water and oils (linseed oil, sunflower oil, olive oil, etc.), for example, can be used as solvents. They make the pigments float to the surface and turn them into a spreadable paste. Egg, milk protein, or wallpaper paste are suitable for use as natural binders. They serve to bind the pigment particles to each other and to the painting surface. A diverse range of earth colours can therefore be produced on the "kitchen table," as it were.

Recipe for coloured pavement chalks
Have the children stir plaster of Paris into water until they get a thin paste. This paste is then coloured by adding some tinting paint (from the hardware store). The children can then pour the mixture into empty matchboxes. The first drying stage takes about one day.
The chalk is then removed from the matchbox and dried for one more day. It can then be used to draw on rough paper or on asphalt.

Recipe for sugar chalks
Self-made sugar chalks have a much more intensive colour than the usual blackboard chalks. To make them, dissolve five teaspoons of granulated sugar in a quarter of a litre of boiled water. Have the children place ordinary coloured blackboard chalks into the sugar solution; the chalks should remain in the solution for at least 30 minutes and become saturated. The children then take them out and let them drain on kitchen paper for a minute. They can then immediately use them for drawing. The luminous effect is visible only after the colour has dried. The sugar chalks keep for about three months in a food storage box. By the way, sugar chalk pictures look particularly lovely on dark paper.

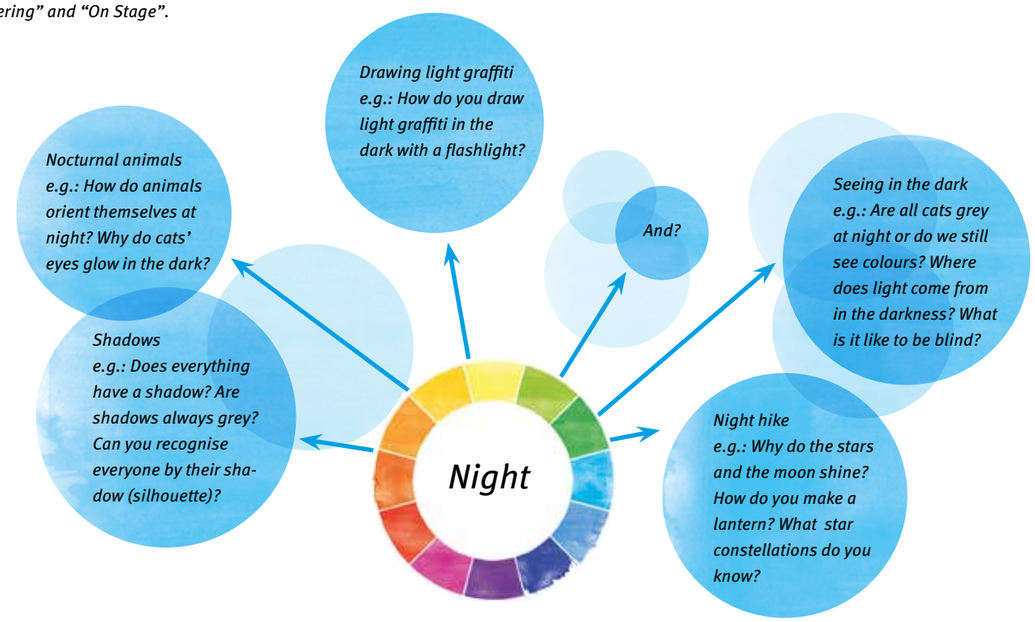
Compile experiences and organise an exhibition

With the children, compile the experiences that they have gathered: What plants were particularly suitable for painting? For example, what fruit or blossom produced a nice red colour? What did the children use to produce blue or green? How was the pigment extracted?
Was it possible to draw with the plant on paper straight away, or was it necessary to produce plant sap or colour pigments first? In order to be able to share the findings with other children and grown-ups, it is advisable to organise an exhibition. Each child contributes something to the exhibition – for example an idea, a drawing or a painting, dyed fabric, photos, or a report. The many experiences that the children have are a frequent source of questions for further investigation. The topic of colour extraction preoccupied the children from Zwergennest Early Childhood Education and Care Centre even weeks after the conclusion of the project. For example, when making jam they discovered charcoal and immediately investigated whether it was suitable for drawing. You should also avail of such opportunities to revisit a topic. In this way, topics close to the children's hearts can be taken up again and again and further pursued.

WITHOUT LIGHT – ADVENTURE IN THE NIGHT

You can find further ideas on the exploration cards "Light and darkness," "What colours can you see in the dark?" and "Light can be directed". In addition, primary school students can use the inquiry cards for children "Sparkling and Glittering" and "On Stage".

A sleepover in the early childhood education and care centre or the after-school centre can be a great opportunity for a project on the subject of "Light, Colours, Vision – Exploring Optics". Involve the children in the planning and preparation of the sleepover. In this way, you can collect lots of ideas and activities that the children would like to try out. Of course, the sleepover could just as well take place at the end of a project (e.g., on the subject of "Day and Night," "Shadows," or "Darkness") – as a special event and a celebratory conclusion for everyone. However, a sleepover is not an absolute necessity. The children's ideas can also be implemented elsewhere in the dark. Possible topics that could emerge from a sleepover in your institution include:



LIGHT AND DARKNESS

We take light so much for granted that we rarely consciously notice it – except in special situations, for example when looking at a lantern, a fire-red sunset, or a glittering ball on the Christmas tree. However, we are immediately aware of the absence of light because then we can no longer see anything. Talk to the children about light and darkness. What experiences have the children had with light and darkness? What feelings do light and darkness awake in them: joy or fear, cheerfulness, security?

The room is turned into a cosy cave

Drape the room with white sheets and arrange comfortable mattresses, blankets, or cushions on the floor for the children. Of course, all the children should help you! Select some gentle, relaxing music or a story that the children would like to hear. And have some coloured lamps ready (you can find inexpensive coloured clamp- or LED lamps at hardware or furniture stores). You could also hang up a disco light in the room (you will find instructions for making one on the exploration card "Light can be directed". Polished crystal drops and other shiny things can be hung up with string.

Light and atmosphere

First, jointly experience absolute darkness in the room, then the dimly-lit atmosphere with a single lamp or candle, and only later the effect of the coloured light on the walls and on your skin and clothes. Try out different light combinations with the children and have them describe their effect and determine which combination makes them feel most comfortable.

Thinking about light and darkness

To produce further light patterns, reflections, and movements in the room, you can give the children small pocket mirrors and flashlights. You can use the conscious experience of darkness to philosophise with the children. For example, jointly consider what it would be like to live in a world of darkness without light. Without the light of the sun, it would be gloomy and very cold on Earth. Without light we could not perceive the splendid colours in our surroundings and we could not see a single thing. Plants could not flourish without light. And what about animals or us humans? Continue spinning these thoughts with the children.

Investigating further

Observe the children. What topics interest them? What would they like to investigate further? Many different research questions are possible, which can be pursued jointly or by individual children. For example: How do shadows occur? Why is light sometimes coloured? What colour is light, actually? Why are there sometimes double shadows? Can I "pass on" light with pocket mirrors?

SHADOW THEATRE

You can find further ideas on the exploration cards "Exploring Shadows" and "Shadows Change". Primary school students can also use the exploration card for children "Shadow Images".

When the children shine flashlights and coloured lights around the room, they can immediately discover many shadows. Pursue these discoveries with them further. Hang a large, white bed sheet up in the room (for example on a washing line) and illuminate the sheet from behind with a light source. A large desk lamp, for example, is well suited for this purpose.

A certified institution (Eilers Kindergarten in Rosenfeld) reports:
Light and Shadow

"In autumn, when it was already getting dark in the late afternoon, we took up an idea to stage shadow plays, which had just been proposed by the children at a children's conference. A shadow theatre was built for this purpose. This kept the project group occupied for quite a long time. Various things were investigated: objects as shadows (are there objects that do not have a shadow?); people as shadows (guessing who people are on the basis of their shadows; shadows can get smaller and bigger); trying out and inventing shadow figures (portrayed using the hands or the body).

A shadow play ("The Star Talers") was developed from this and was staged at the Christmas party for the families. While they were working on the play, the children were constantly discovering rays of light that still managed to find their way into the darkened room. These rays of light produced bright colours on the walls, as if by magic. So the children had to get to the bottom of that phenomenon, too. This led to the next project, "Light and Colours".

Shadow mysteries

Now it is possible to stand behind the shadow curtain and – concealed from view – create shadow images. For example, several children can go behind the curtain while all the others try to guess which shadow belongs to which child. Can the children be recognised on the basis of their hairstyle or their height? Is it possible to find out what clothes the children are wearing? And what colour the clothes are? It gets more difficult and funnier when the children behind the shadow curtain change their shadows – for example by holding a cushion in front of their tummies, putting a colander on their heads, or making their noses longer with a cardboard tube. Of course, objects can be presented behind the curtain, too, and the audience has to guess what object casts the shadow.

However, bear in mind that the shadow cast does not always look like the object in question. Shadows can change their shape and look distorted. For example, depending on how you hold a plastic funnel in front of the light source, very different shadows can be created. Sometimes the funnel can look like a ball or a pan, sometimes like Pinocchio or a flying saucer; and sometimes it can actually look like a funnel. Guess with the children what object is actually behind the shadow cast.

Colourful doppelgangers

Most shadows are grey. Can you also succeed in colouring shadows? A collection of materials such as coloured fabrics, transparent coloured foil, sheets of thin, transparent coloured paper, beakers, and coloured water give the children ideas about how to pursue this question. What do the children observe when they pour coloured water (e.g., fruit tea) into a glass and place it in front of the light source?

However, coloured shadows do not only occur when you use transparent coloured materials to produce shadows. They also occur when you use coloured light from the very start. Use the coloured (clamp) spotlights in red, blue, and green. The lights should be very close to each other. If the children hold their hands between the lamps and the wall onto which the shadows are cast, lots of brightly coloured shadow hands will be produced. What does the shadow look like when only one light is on?

Shadow space

To investigate with the children the fact that a shadow is not just a two-dimensional image but also an actual space, have them search for a shadow of a cuddly toy or a doll. Does the cuddly toy or the doll fit into the shadow completely? How can you tell that it fits completely into the shadow? Where are the contours of the shadow? Jointly fill the entire shadow space with building bricks. First, fill the surface. And how high must the children build?

Theatre scenery

With the children, build the necessary scenery for the shadow theatre. What about building the skyline of a big city, for example? To do so, the children place or stick empty Tetra pack cartons, plastic yoghurt pots, small cardboard boxes, glasses, tins, and lids on top of each other to create various high-rise buildings and towers. If you have an overhead projector at your disposal, the children could also draw the scenery they need for the play on transparencies. When a transparency is placed on the surface of the projector, and the projector shines on the bed sheet, the children's drawings will appear.

Pool experiences and use them for the joint shadow play

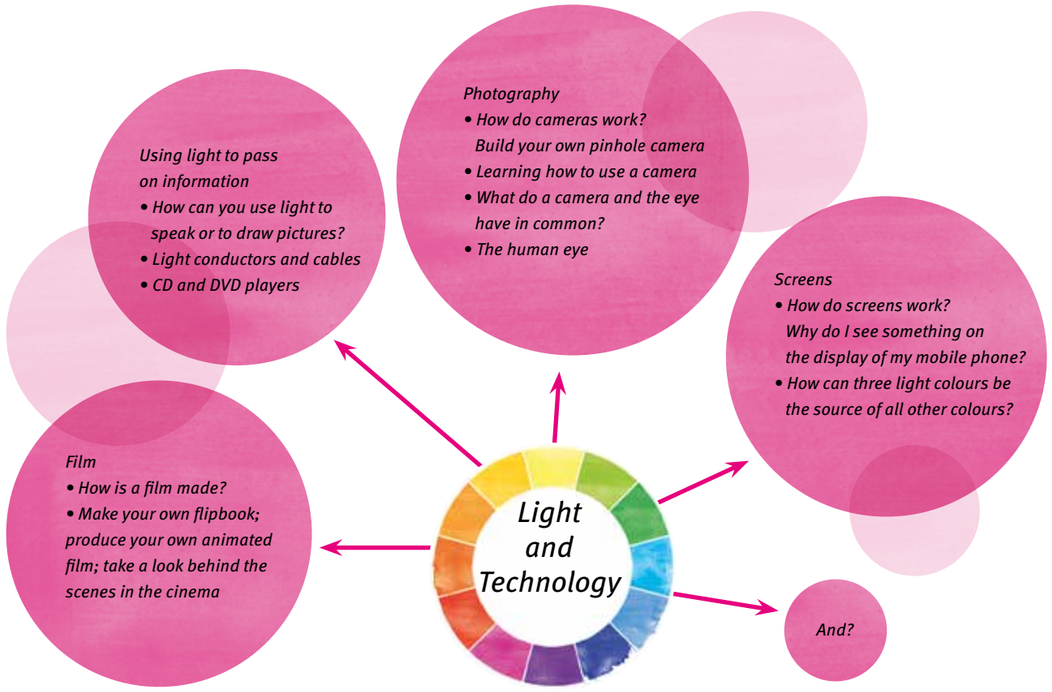
Like the early childhood education and care centre in the above project example, avail of the children's diverse experiences with shadows for the shadow theatre. With their inquiry activities, all the children can make a contribution. Are coloured shadows needed for the play, for example? Which children investigated coloured shadows and can now help out with this? How can big and small shadows be simultaneously projected onto the screen? Or two shadows of the same figure? Include the children – and their discoveries.

Moreover, many of the children's experiences offer starting points for further inquiry activities and give rise to questions such as: How can you pick a shadow up? Do shadows have weight? Is it possible to cover a shadow up? Is the shadow of a spotted cow also spotted? Who manages to be faster than their shadow? And what is a shadow actually good for?

HOW DOES THE PICTURE GET INTO THE TELEVISION?

You will find further ideas on the exploration card "Light can be directed".

Explore the technical side of light with the children. Whether it be a mobile phone, a flat-screen TV, or a CD player – without optical technologies, many appliances that are a taken-for-granted part of our lives and the lives of the children would be unthinkable. There are many possible project topics in this area. A visit to the cinema, the use of mobile phones, or working together on the computer could trigger relevant questions.



Be attentive to the children's topics and take up their interests. As the following example shows, a camera that one of the children brought into an early childhood education and care centre was the starting point for a whole project:

A certified institution (St. Peter and Paul House for Children in Aicha vorm Wald) reports:

"One morning, one of the children brought in a camera – the other children were immediately enthusiastic about it. So, first, we set off on a photography tour of the village; the children brought along their own cameras. Afterwards on the computer, we made unique collages out of the photos they had taken, and we created a tricky village puzzle for the parents.
Meanwhile, several children expressed the wish not only to take photos but also to make a proper film. The father of one of the children agreed to act as director and to make a short film on the subject of 'Friendship' with the children (it can be viewed on our website: www.kita.aichavormwald.de/projekte).

He allowed himself to be interviewed by the children and provided all the equipment for the exploration and investigation. The children were delighted. The children also organised their own 'film show' on the subject of 'Conflict and Reconciliation'. They eagerly built and painted the individual scenes. But how is this done in the 'real' cinema? To find out, we looked at a documentary, which answered the questions. Of course, the right styling is a must for a film star. So a photographer and a hairdresser skilfully ensured that the young performers looked their best.

Because the children were still keenly interested in the topic, some of them built a real pinhole camera. They made sketches, 'read' their way through illustrated instructions, found information on the Internet, helped each other, and thus found answers to technical questions themselves. The development of the film roll revealed that the pinhole camera actually worked! The children looked at the pictures proudly and showed them to the others."

Have the confidence to get to the bottom of supposedly difficult research questions on the subject of "Light and Technology" with the children. The following chapter provides lots of ideas and background information on this topic.[18]

Light language

Light can be used to transport information and make it visible. The idea behind this is not new. Rather, it is the same as that on which Morse code and the smoke signals used by indigenous peoples are based. Two signs are enough to encode, represent, and save language, images, music, and much more besides.

Nowadays, Morse code is hardly used at all, and nobody sends smoke signals, but the basic idea that a language can manage with just two signs has remained. This is also known as the binary code ("bi" means "two"). "Light on" is one binary digit, or "bit"; "Light off" is the other. "Light on" and "Light off" are thus the simplest language in the world – and also the most important language in technology. The children can easily understand it. All they need is a flashlight to switch on and off.

[18] *Many of the ideas for practical application were inspired by this brochure, which was published by the German Federal Ministry of Education and Research (BMBF) and can be downloaded free of charge at www.faszinationlicht.de.*

Primary school students can also explore the binary code with the exploration card "Light Language" and transmit their light signals through a light conductor made of aluminium foil.

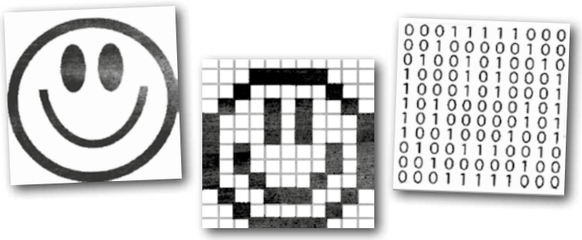
0 = Light off, 1 = Light on

A = 00001	L = 01100	W = 10111
B = 00010	M = 01101	X = 11000
C = 00011	N = 01110	Y = 11001
D = 00100	O = 01111	Z = 11010
E = 00101	P = 10000	Ä = 11011
F = 00110	Q = 10001	Ö = 11100
G = 00111	R = 10010	Ü = 11101
H = 01000	S = 10011	ß = 11110
I = 01001	T = 10100	_ = 11111
J = 01010	U = 10101	
K = 01011	V = 10110	

A	Light off	Light off	Light off	Light off	Light on
U	Light on	Light off	Light on	Light off	Light on

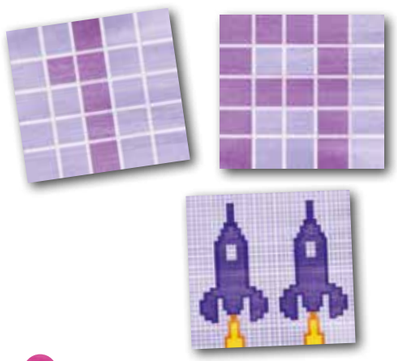
Pictures on the screen

With two signs, you can not only write but also draw. For example, a smiley can be converted into the colours black and white or represented with the digits 0 and 1.



More knowledge

The signs in black and white (or 0 and 1) could also be called pixels. A pixel is the smallest element – the "atom", as it were – of an image. It can be a dot on a screen, a cell in an image sensor, or, as in the above example, an individual square on a sheet of squared paper. Like a mosaic, an image is made up of many little pixels. The level of detail of an image depends on how close together the pixels are. The more pixels per image, the higher the level of detail.



With the children, try producing such (relatively coarse-grained) pixel images. At first, it is easier to draw a frame around a small area on a sheet of squared paper, for example a field comprising 5 x 5 squares. Each field thus consists of 25 squares – that is, 25 pixels. Then have the children draw whatever signs or pictures they want in the framed field by colouring some of the squares (or pixels) black and leaving the others white. Letters or numbers are very suitable at the beginning. As the children become more proficient, they can increase the size of the field and even decorate whole pages of squared paper with coloured pixel images.

More knowledge

In the case of a colour screen, on the other hand, each pixel is composed of three dots in the colours red, green, and blue, from which all the other colours can be produced. To "mix" the colours, the individual coloured dots are dimmed or brightened to a greater or lesser extent. This is done by using a special liquid, or more precisely, a liquid crystal. This technology is known as "liquid-crystal display" (LCD). That is where the term LCD screen comes from.

With the children, examine a colour screen. To do so, use strong magnifying glasses or transparent marbles, which can be held up to the screen. Can the children detect the dots in the three colours? Each pixel on the screen is made up of a blue, a green, and a red dot.

But how can all the other colours be produced from these three colours? Modern computer monitors or TV screens use additive colour technology. At this point, a digression on mixing light colours would be appropriate. Explore with the children how all the other colours are derived from red, green, and blue. To do so, have them cover flashlights with coloured crepe paper and shine the flashlights on a white wall in a darkened room. What happens when two light colours strike the wall and overlap. Are the mixed colours that are produced in this way the same as those in a paint box?

On a colour screen, however, the light colours are not represented on top of each other but rather beside each other. Because the little dots are so close to each other, they cannot be distinguished by the observer. With the children, look at the different coloured areas on the screen through a marble. Is the colour grid in the marble always the same. What colours can the children detect in the marble?

Use the exploration card "Now things get colourful" or the exploration card for primary school students "On Stage".

Posters and billboards

When only a few pixels are available, images look very coarse-grained. The pictures that the children drew earlier on squared paper, for example, comprised only 5 x 5 squares = 25 pixels. By contrast, a standard photo has over 4,000,000 pixels (or 4 megapixels).

Set off with the children in search of pixel images. Suitable sources are large billboards in the vicinity of your institution – for example in the car park of your local supermarket or at the railway station. Jointly examine how the photo is composed of individual pixels. These pixels are easily recognisable if you step right up to the billboard: The image looks very coarse-grained – you can only guess what it is supposed to represent. The further away from the billboard you go, the more the pixels assemble to form a complete image. But can you still see the individual pixels?

At this point, you could start an art project with the children, for example. Jointly create a large picture composed of lots of pixels. Children can also grasp the principle of creating a picture from lots of individual picture elements when they make peg images or build things out of little Lego bricks.

Images become film

With the help of a flipbook, you can now explore with the children how individual images become a proper film: On lots of small, identical-sized slips of paper (e.g., post-it notes), the children draw a simple motion sequence (e.g., a dot that gets bigger and bigger; the sun setting on the horizon and rising again; a flower that is growing, etc.). Only one small detail changes from picture to picture. Then the flipbook is "played back". Do the children still recognise the individual pictures?

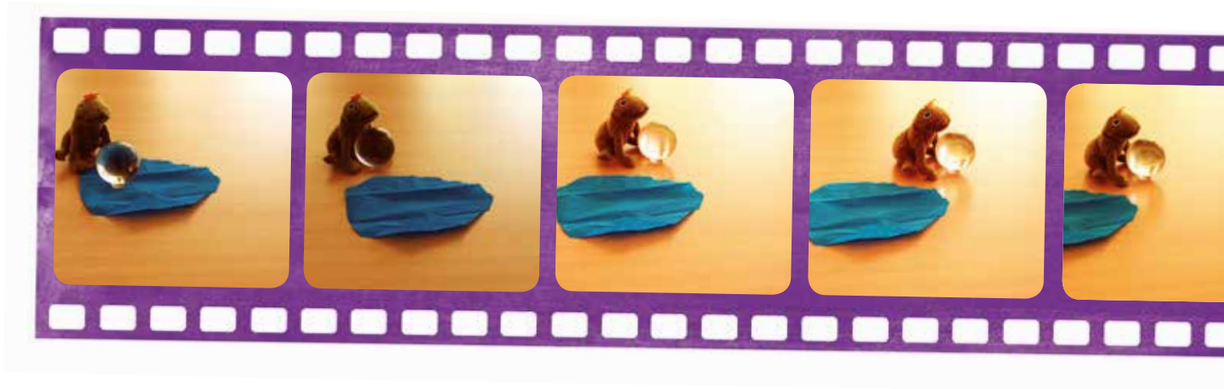
More knowledge

When we quickly flick through a flipbook composed of lots of individual images, we perceive it as a single fluid motion – like a film. The sensory cells in our eyes (the photoreceptors) cannot work at just any speed. Rather, they need about one-fifteenth of a second to distinguish a new sensory impression from the previous one.
So when more than 15 individual images appear per second in quick succession, we get the impression of continuous motion. Instead of "15 times per second," one can also say "15 Hz (i.e., hertz, called after the physicist Heinrich Hertz).
From a frequency of about 20 Hz onwards, most of us perceive sequences of images as fluid, continuous motion. Modern TV sets usually generate 100 images per second. However, not all animals are as slow as we are at processing light stimuli in the eye. For some birds, for example, a TV movie is like a slide-show because they can distinguish individual images up to a frequency of 150 to 200 per second.

Flipbooks can also be made in a very different way: For example, the children could take a photo every ten seconds during an activity such as tidying up the room. If you look at the photos on the computer later in quick succession using the slide-show option, you get a little time-lapse movie.

You can also jointly create an animated film. This is quite arduous and demands a lot of perseverance on the part of the children and the facilitator of learning. Jointly come up with a simple sequence, for example a snail race or the movement of a cuddly toy, such as a frog. For each photo, the children move the figures a little bit further. Once they take their hands away, the shutter-release button of the camera is pressed. Little by little, the previously agreed story is enacted.

Just like the "tidying-up" example above, the photos can be turned into a "movie" by making them into a slide-show on the computer and playing it at fast speed.[19] In one second of a professional animated film of the kind we see on TV, there are about four different individual images. Thus, for one minute of animated film, up to 240 images are required.



At the end of their technology project, the children will undoubtedly be proud of their discoveries and experiences. An exhibition is a good way of making these accessible to other children in your institution. The works of art that have been produced can be presented and appreciated. At the ceremonial opening of the exhibition, the short film can be shown. What form should an attractive exhibition take, in the children's view. What can be shown, and how? Should there be popcorn at the short film or would it be better to play the film in a continuous loop. Can a grown-up help with this?

Pool, prepare, and present experiences and organise an exhibition

[19] *Apps with which photos can be automatically taken at intervals and then played as a movie are available for tablet computers. Many examples of such stop-motion movies can be admired on the Internet. The models are made of plasticine (modelling clay) or Lego bricks. In the first case, the stop-motion animation is known as "clay animation," in the second case, it is called a "brickfilm".*

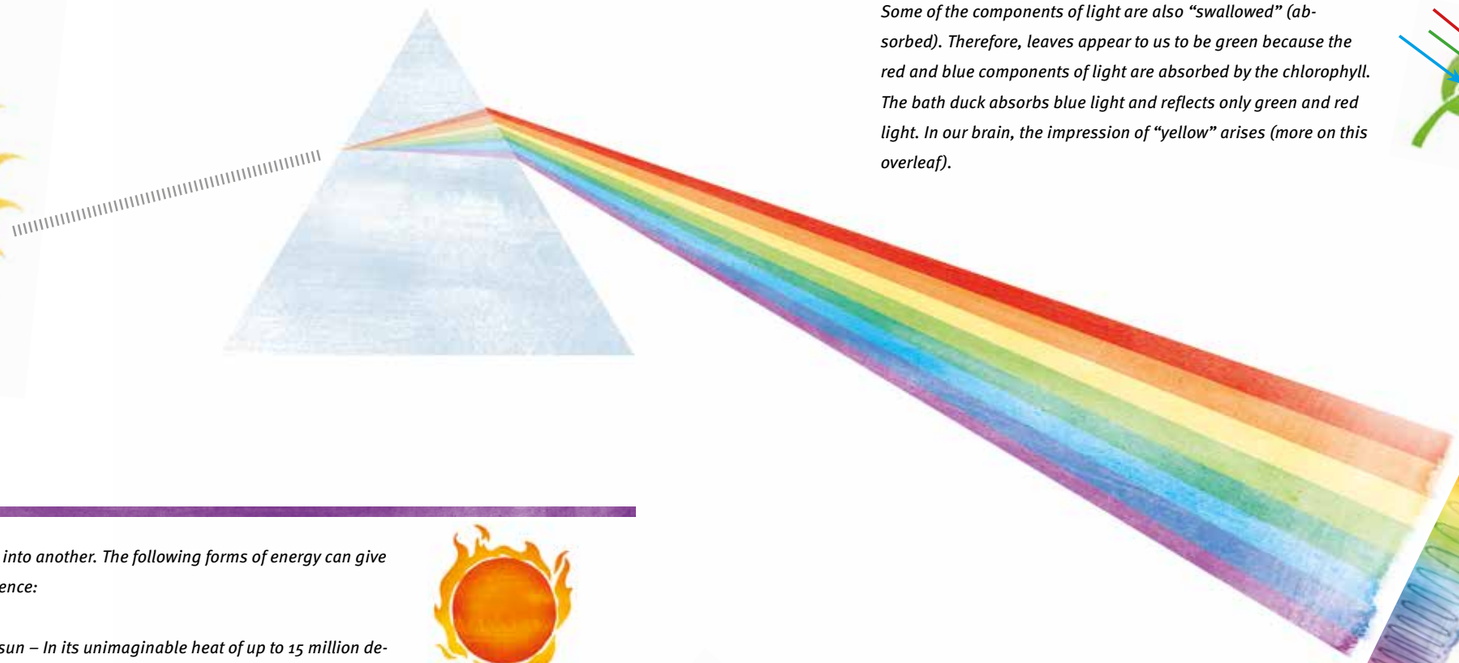
LIGHT

WHAT IS LIGHT?

Light is energy. The energy in light moves in waves. Hence, light has wave-like properties. Visible light, microwaves, X-rays, television and radio waves – to name but a few – are different types of electromagnetic waves. Depending on the wavelength, that is, the distance from one wave "crest" to the next, it can be assigned different properties.

The light region that is visible to the human eye contains only a small section comprising wavelengths of 380 to 750 nanometers. The short wavelengths in this section appear to us to be blue, the medium wavelengths appear to be green, and the long wavelengths appear to be red. The shorter the wavelengths are, the more energy they contain.

In order to be able to describe all the properties of light, it is necessary to supplement the wave model of light with a model of light as a stream of small, energy-rich particles called photons. Hence, light also has particle-like properties. The nature of light has not yet been conclusively researched. However, with these two notions, almost all properties of light can be described.



HOW DOES LIGHT ARISE?

Light arises through the conversion of one form of energy into another. The following forms of energy can give rise to light, which we perceive as brightness or luminescence:

High temperatures, *for example the nuclear fusion in the sun – In its unimaginable heat of up to 15 million degrees Celsius, enormous amounts of energy are released when hydrogen is fused to form helium. The sun emits this energy in the form of heat and light.*

Electricity, *which is transformed into heat energy and light, for example in the filament of an old-fashioned light bulb. In LEDs, electricity is converted into light more efficiently because very little heat is produced. Therefore, LEDs are classified as energy-saving lamps.*

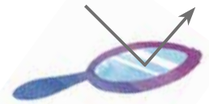
Burning – *Here, the energy reserve of burnt things is converted into light energy, for example in the case of a campfire, a candle, or a gas lamp.*

HOW DOES LIGHT SPREAD OUT?

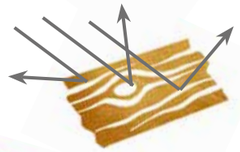
Light moves extremely fast – namely, with the speed of light (in a vacuum, 299,972 kilometres per second). That is the greatest speed that occurs in nature or technology. If there were such a thing as an aeroplane that could travel at the speed of light, it could circle the Earth eight times per second. When light strikes an object, the following can happen:

1. It is thrown back (reflection).
2. It is thrown back in different directions (scattering).
3. It is "swallowed" by the object (absorption).

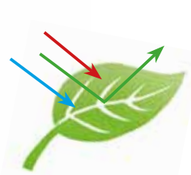
Reflection
The light emanating from a light source can spread out only in straight lines. Unlike water, for example, it cannot avoid an object and flow around it. When the rays of light strike an object, they mainly bounce off the surface, like a ball.

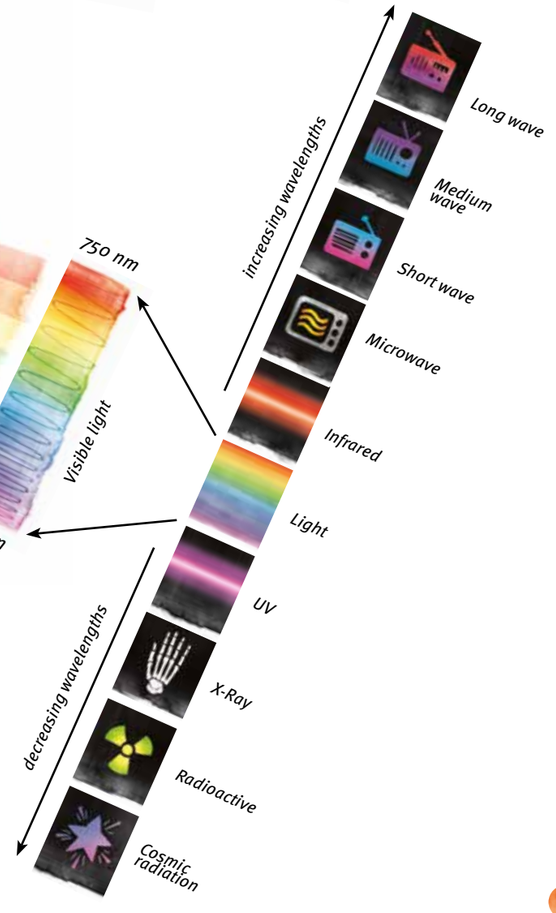


Scattering
However, the surface of an object is never absolutely smooth. Rather, it has diverse tiny irregularities – you can feel them if you run your fingers over a house wall, a leaf, a piece of wood, etc. Hence, the light components are reflected in many directions and thus scattered.



Absorption
Some of the components of light are also "swallowed" (absorbed). Therefore, leaves appear to us to be green because the red and blue components of light are absorbed by the chlorophyll. The bath duck absorbs blue light and reflects only green and red light. In our brain, the impression of "yellow" arises (more on this overleaf).





HUMAN VISION

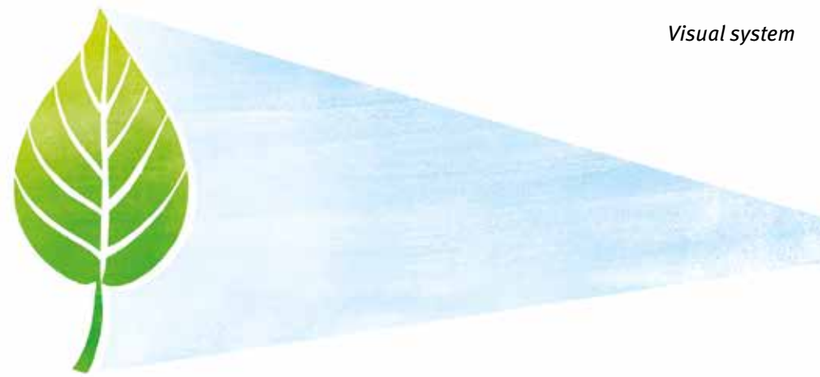
HOW DO WE SEE?

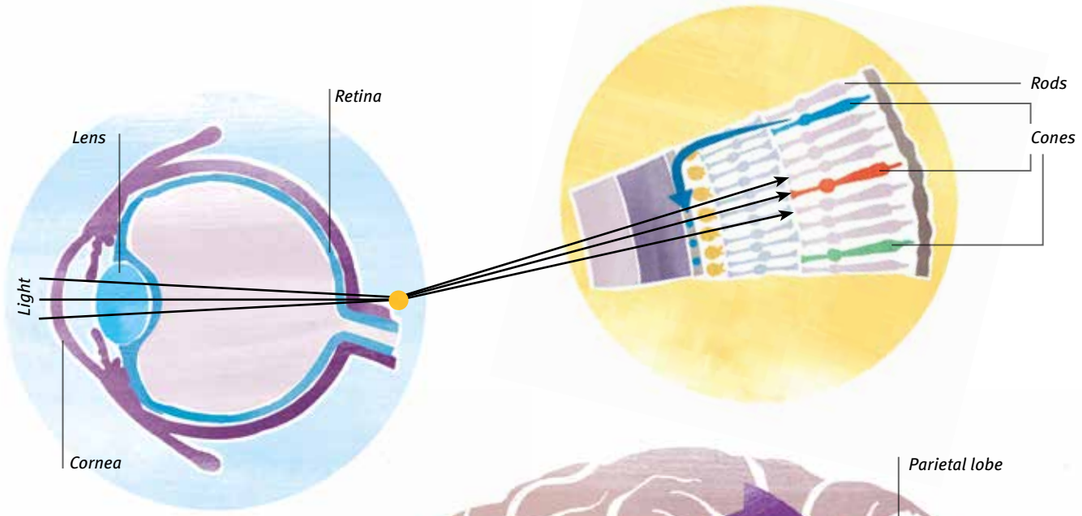
Light is constantly being reflected by objects. When we see something, reflected light from our surroundings enters the eye via the lens system and reaches a layer of sensory cells on the retina. The brain analyses the stimuli perceived by the sensory cells and generates an image of the environment.

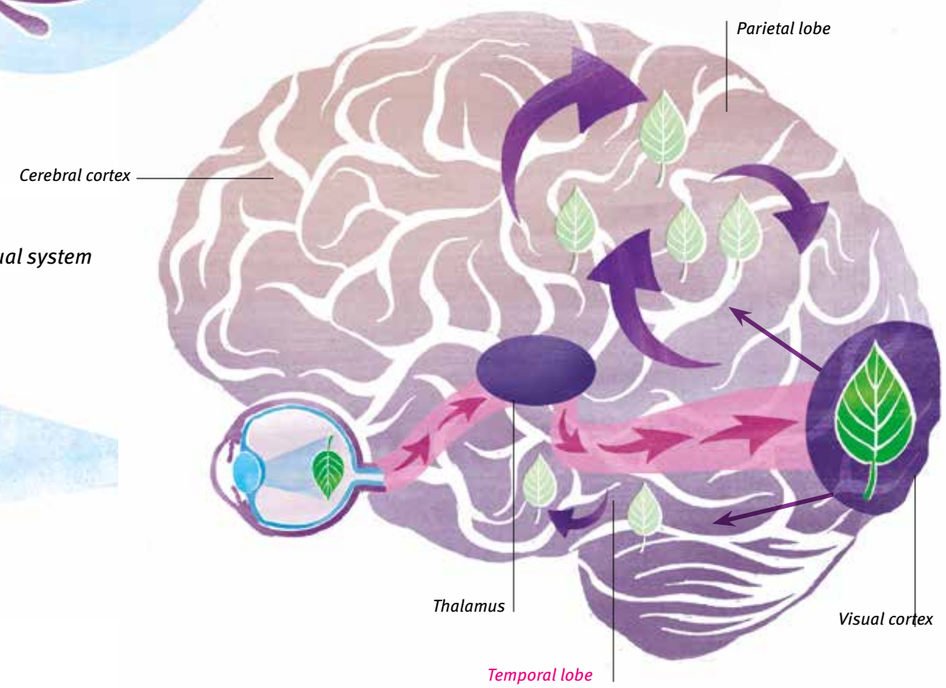
The retina contains different types of cells – cones and rods. Because rods are very sensitive to light, they also function under low light conditions; moonshine or starlight suffices. However, rods enable us to perceive only differences in brightness – in other words, shades of grey – but not colours. The cones, on the other hand, enable us to distinguish colours. However, cones function only under high light conditions. That is why we can hardly detect colours in the dark.

The eye is a hollow ball filled with fluid – the vitreous body. The protective cornea is similar to a window through which the light enters. The pupil, the lens, and the vitreous body are located behind the cornea. The eye works like a camera. The parallel light waves that enter the eye are bundled in such a way that they converge at the focal point of the retina. In this way, the lens in conjunction with the vitreous body generates an upside-down image of the outside world, which is turned right-side-up again by the brain.

The visual centre – the visual cortex – is located in the cerebral cortex at the back of the head. From here, the information about what has been seen is compared with familiar sensory and memory impressions and passed on to other parts of the brain.
Only then do we recognise what the thing we have seen actually is, where it is located in space, and whether it is moving, for example.





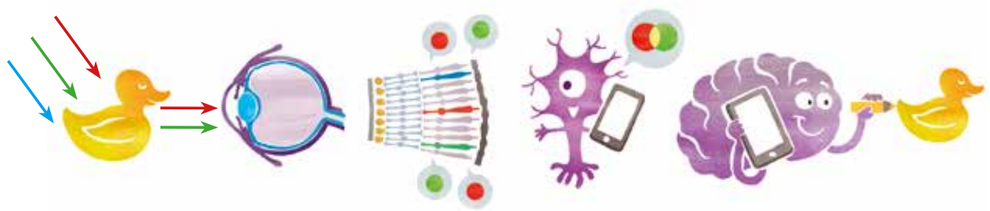


Visual system

HOW DO WE SEE COLOURS?

Colours are not something that occur absolutely in nature. All colour impressions that we have when we look at an object are generated by our brain. The cones in the retina of the eye respond to a particular wavelength of the light. There are three types of cones: one that responds to long-wave light, one that responds to medium-wave light, and one that responds to short-wave light. As soon as the cones recognise a wave, they pass this information on to a nerve cell, where it is bundled and transmitted via the optic nerve to the brain.

And it is there that our colour impression arises. In the case of short waves, we see blue; in the case of medium-wave light, we see green, and in the case of long waves, we see red. However, in most cases, waves of different lengths enter the eye at the same time. In other words, different types of cones are simultaneously stimulated to a different extent and pass their information on. This results in the impressions of mixed colours – yellow, orange, purple, pink, brown, dark blue, light blue, etc. – in the brain. Because colour vision takes place in the brain, it is also determined by psychological factors. Hence, experiences and moods can influence our colour perception, and individual variance is considerable.

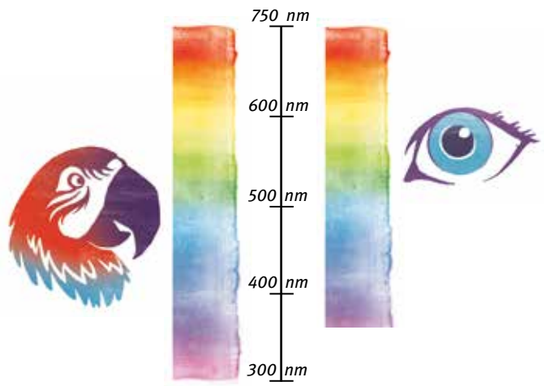


DO ANIMALS SEE DIFFERENTLY THAN HUMANS?

Many species of animal see light in frequency ranges that are not accessible to the human eye. For example, some fish and butterflies can see into the ultraviolet range of the spectrum, which provides them with additional information at dawn and at dusk.

Ultraviolet (UV) light can be detected by many insects, mice, fish, and birds. To attract pollinating insects, many flowers have striking patterns that can be seen only in ultraviolet light. Half of all bird species have plumage that reflects UV light. This makes it easier for them to distinguish between the males and females of the species.

Visible Light



REFERENCES, TIPS, AND LINKS

REFERENCES

Berk, L. E.: Entwicklungspsychologie. Pearson Studium, München 2005.

Brawata, I.: „Blindes Baby, lach doch mal!“ Fragen an Dr. Werner Hecker zur Wahrnehmung und Entwicklung blinder Kleinkinder. Horus. Marburger Beiträge zur Integration Blinder und Sehbehinderter. Deutscher Verein der Blinden und Sehbehinderten in Studium und Beruf e. V., Marburg 2009 (4).

Das Gute muss siegen. Star Wars – ein Projekt, in dem Geschichten wanderten. In: **Betrifft Kinder**, Heft 01–02, 2013, pp. 21–27.

Gropengießer, H.: Didaktische Rekonstruktion des Sehens. Wissenschaftliche Theorien und die Sicht der Schüler in der Perspektive der Vermittlung. Didaktisches Zentrum, Oldenburg 2007 (2nd edition).

Guesne, E.: Die Vorstellungen von Kindern über Licht. Physica didactica, 1984 (11), pp. 79–98.

Guesne, E.: Light. In: Driver, R., Guesne, E., Tiberghien, A. (Eds.): Children’s Ideas in Science. Open University Press, Milton Keynes, 1992.

Haug-Schnabel, G., Bensel, J.: Vom Säugling zum Schulkind – Entwicklungspsychologische Grundlagen. Kindergarten heute. Wissen kompakt/Spezial. Herder, Freiburg 2004.

Heybrock, E., Krause, R.: Wir gehen ins Internet – mit Licht. Lukas Experimente. VDI Technologiezentrum GmbH (Projektträger des BMBF für den Bereich Optische Technologien), Düsseldorf 2007.

Jacobs, D.: Projektarbeit. Kitaleben mit Kindern gestalten. Verlag das Netz, Kiliansroda 2012.

Katz, L. G., Chard, S. C.: Der Projekt-Ansatz. In: Fthenakis, W. E., Textor, M. R. (Eds.): Pädagogische Ansätze im Kindergarten. Beltz, Weinheim 2000, pp. 209–223.

Konrad, K., Fink, G. R.: Entwicklung von Wahrnehmungs- und Aufmerksamkeitsprozessen. In: Herpertz-Dahlmann, B., Resch, F., Schulte-Markwort, M., Warnke, A. (Eds.): Entwicklungspsychiatrie. Schattauer, Stuttgart 2008 (2nd edition), pp. 161–174.

Mai, I.: Flohmarkt der Ritter. In: Institut für Bildung und Entwicklung (Hrsg.): Projektarbeit in Kitas. Schulfähigkeit, Spaß und Lebenskompetenz. Don Bosco, München 2006, pp. 50–64.

Murmann, L.: Physiklernen zu Licht, Schatten und Sehen. Eine phänomenografische Untersuchung in der Primarstufe. Logos, Berlin 2002.

Murmann, L.: Phänomene erschließen kann Physiklernen bedeuten. Perspektiven einer wissenschaftlichen Sachunterrichtsdidaktik am Beispiel der Lernforschung zu Phänomenen der unbelebten Natur. In: www.widerstreit-sachunterricht.de, 2004 (3).

Murmann, L.: Licht macht hell – und was ist dunkel? Anregungen für das 1. und 2. Schuljahr. In: Grundschule Sachunterricht. Friedrich Verlag, Seelze 2010a (3), pp. 7–11.

Murmann, L.: Dem Licht auf der Spur. Licht begreifen durch Beobachten, Handeln und Denken: Anregungen für den Sachunterricht im 3. und 4. Schuljahr. In: Grundschule Sachunterricht. Friedrich Verlag, Seelze 2010b (3), pp. 12–15.

Reggio Children (Eds.): Alles hat einen Schatten außer den Ameisen. Wie Kinder im Kindergarten lernen. Beltz, Weinheim 2005 (2nd edition).

Rieck, K.: Themenfeld Licht und Sehen. In: Kahlert, J., Demuth, R. (Eds.): Wir experimentieren in der Grundschule. Aulis Verlag, Hallbergmoos 2010 (2nd edition), pp. 80–140.

Schröder, J.: NaWi – Unterricht an inklusiven Schulen. Unveröffentlichte Hausarbeit. Katholische Hochschule für Sozialwesen in Berlin 2014.

TIPS FOR READING, LINKS

On the subject of “Project Work”

Henneberg, R., Klein, L., Schäfer, G. E.: Das Lernen der Kinder begleiten. Bildung-Beziehung-Dialog. Ein Fotoband. Kallmeyer in Verbindung mit Klett, Seelze 2011.

Institut für Bildung und Entwicklung (Eds.): Projektarbeit in Kitas. Schulfähigkeit, Spaß und Lebenskompetenz. Don Bosco, Munich 2006.

Jacobs, D.: Projektarbeit. Kitaleben mit Kindern gestalten. Verlag das Netz, Kiliansroda 2012.

On the subject of “Light, Colours, Vision – Exploring Optics”

Allerlei Sonniges. Kreative Ideen und Materialien für Krippe, Kindergarten und Hort. Mathematik & Naturwissenschaften. Olzog, Ausgabe 05/2006. Available online at: **www.edidact.de**

Cottin, M., Faría, R.: Das schwarze Buch der Farben. Fischer Schatzinsel, Frankfurt a. M. 2008.

Duprat, G.: Was sieht eigentlich der Regenwurm? Die Welt mit den Augen der Tiere sehen. Knesebeck Verlag, München 2014.

Krasny, E.: Warum ist das Licht so schnell? Eine Reise durch die Welt des Lichts. Niederösterreichisches Pressehaus, St. Pölten 2005.

Krouse Rosentahl, A., Lichtenheld, T.: Ente! Hase! Baumhaus Verlag, Cologne 2010.

Leathers, P.: Schwarzhase. Gabriel Verlag, Stuttgart 2013.

Leizgen, A. M.: Forschen, Bauen, Staunen von A bis Z. Beltz, Weinheim 2014. Four volumes from this series of 26 books are thematically relevant: Farbe, Licht, Sonne und 3D.

Reggio Children (Eds.): Alles hat einen Schatten außer den Ameisen. Wie Kinder im Kindergarten lernen. Beltz, Weinheim 2005 (2nd edition).

Rettkowski-Felten, M., Jordan, M.: Spieglein, Spieglein an der Wand … Das Spiegelbuch für Kindergarten, Hort und Grundschule. Verlag das Netz, Berlin 2008.

On the Internet (German-language links)

www.astronomiekiste.de/mond – Child-oriented information about outer space and the moon

www.erste-hilfe-fuer-kinder.de/Giftpflanzen/giftpflanzen.html – The most common poisonous plants in nature, the garden, and the household, with images and a downloadable poster

www.farbimpulse.de – Social and scientific findings on the subject of colours for grownups

www.faszinationlicht.de – *Lukas Geschichten* and *Lukas Experimente* are a series of brochures for children. The experiments deal with optical technologies, among other things. Enter the word “Lukas” in the full-text search box.

www.kindernetz.de/tigerentenclub/spiel/spiele/farbenmischen – Colour mixing as a game on screen with the characters Tigerente (Tiger Duck) and Frog

The film “Svyato” by Victor Kossakovsky at www.youtube.com – The two-year-old son of the documentary filmmaker sees himself in the mirror for the first time and explores his mirror image. You can watch him experiencing different cognitive phases.

ACKNOWLEDGEMENT

This brochure features ideas and suggestions from several early childhood education and care centres, after-school centres, and primary schools. The team of the “Haus der kleinen Forscher” Foundation would like to say a very warm thank you to them all.

The children of St. Michael and Herz Jesu Early Childhood Education and Care Centres in Berlin and the students of the Elisabeth Abegg Primary School, the Wedding School, and the Nelson Mandela International School in Berlin were open and inquisitive advisers. With their ideas and eagerness to learn, they helped us to enrich the new edition of this brochure and the accompanying card sets. We would also like to say a special word of thanks to the teachers and educators there for their support. We used project descriptions from St. Michael Catholic Day Centre for Children in Neuss, Zwergennest Early Childhood Education and Care Centre in Rosenfeld, St. Agnes Catholic Kindergarten in Zülpich-Lövenich, and St. Peter and Paul House for Children in Aicha vorm Wald.

We also received creative and exciting suggestions from Am Kleistpark Early Childhood Education and Care Centre in Berlin, the Protestant Kindergarten in Anhausen, Uns Windroos Early Childhood Education and Care Centre in Bad Doberan, and Frundbergstrasse Municipal Kindergarten in Munich. We would also like to thank Prof. Lydia Murmann for her expert comments. Many thanks to all our helpers!

IMPRINT

First edition

Publisher: “Haus der kleinen Forscher” Foundation

Person responsible: Dr Margret Lohmann

Project manager: Dr Stefanie Kademann

Concept and editing: Anne Großkurth, Dr Stefanie Kademann

Editorial assistant: Christine Günther

Production manager: Sabine Pauli

Illustration and design: Tim Brackmann, Berlin

Printer: Format Druck und Medienservice GmbH, Berlin

Cover photo: Christoph Wehrer, Berlin

Photos: p. 4 KOPF & KRAGEN Fotografie, Berlin; pp. 6, 29, 30, 32, 35, 36, 38, 39, 40, 41, 43, 44, 45, 49, 50, 51: “Haus der kleinen Forscher” Foundation, Berlin; pp. 8, 12, 16, 18, 24, 29, 36, 43, 45: Christoph Wehrer, Berlin; pp. 26, 34, 35: Thinkstock: Elenathewise, Ivanov Arkady Nicolaevitc, FooTToo; pp. 27, 50: iStock: Blackzheep, Ekaterina Minaeva, Havana1234; p. 37: Marion Freude, Berlin

“Haus der kleinen Forscher” Foundation
Rungestraße 18
10179 Berlin, Germany

Tel +49 30 27 59 59 -0
Fax +49 30 27 59 59 -209
info@haus-der-kleinen-forscher.de
www.haus-der-kleinen-forscher.de

Dieses Druckerzeugnis wurde mit dem Blauen Engel gekennzeichnet.