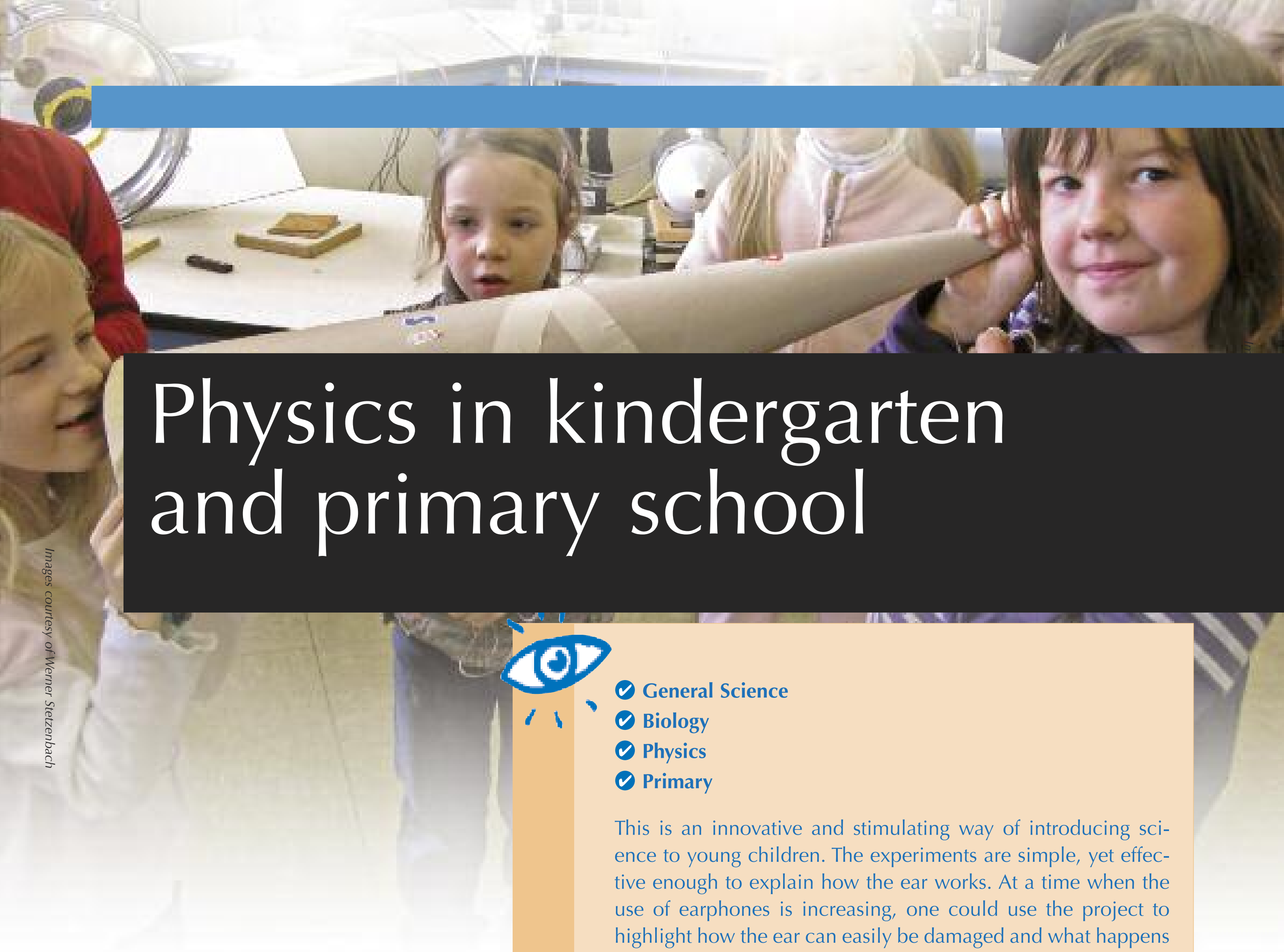


Images courtesy of Werner Stetzenbach

Physics in kindergarten and primary school

Werner and **Gabriele Stetzenbach** tell us how kindergarten and primary-school children discover the world of physics together with secondary-school students as their mentors. Why not try it in your school?

REVIEW

- General Science
- Biology
- Physics
- Primary

This is an innovative and stimulating way of introducing science to young children. The experiments are simple, yet effective enough to explain how the ear works. At a time when the use of earphones is increasing, one could use the project to highlight how the ear can easily be damaged and what happens in such cases.

The article can be used by two separate audiences: the first are kindergarten and primary-school teachers. They can use the experiments detailed in this article and the additional activities developed by the project (available online) in their classroom. Some kindergarten and primary-school teachers may find it difficult because they do not have the necessary science background; this problem may be overcome through prior preparation, the help of a science specialist or the assistance of prepared secondary-school students, as in the presented project. Suggested background reading material can also be found in the 'Resources' section.

For secondary-school science teachers, the article provides details of how to set up a similar project with their students. If secondary-school students are involved, then such a project can be very motivating for them and should also help them to grow into more responsible adults.

The experiments are ideal to use for primary/kindergarten science, but may also be used in integrated/coordinated science. They are helpful for biology lessons to teach about the ear and hearing, and for physics lessons, to teach about the transmission of sound, the ear as a real-life application for the transmission of sound, or cleaning using ultrasound (jostling of dirt particles instead of the jelly babies).

Paul Xuereb, Malta

Setting up a similar project with your students

BACKGROUND

Secondary-school students have a different perspective from teachers and educators, which can be very helpful when dealing with small children, as they can be easily accepted as 'big brothers or sisters'. The secondary-school students involved in our project benefited a great deal from the experience: they learned to give presentations, became more self-confident and improved their organisational skills – all without the pressure of a standard classroom situation. Additionally, they got a first-hand insight into the work of teachers, educators, scientists and engineers.

A team should consist of 4-5 secondary-school students and a supervising teacher. In an initial brainstorming session, let the students come up with their own ideas; this will motivate them to be very creative. They may find it helpful to consult books and websites of teaching activities. By letting each student work on a separate topic, students of different abilities can be involved. The teacher should moderate the meetings, provide the experimental materials and help to set up the experiments.

To inspire fun and curiosity, experiments should be easy to set up and, ideally, should involve several senses at once. When the younger children are able to experiment by themselves, they often express and test their own ideas.

It is important to contact potential project partners (kindergartens or primary schools) early on in the project. Whereas kindergartens tend to be open to many scientific subjects, the experiments for primary schools may need to fit the curriculum topics taught in science or nature lessons, if the subject exists.

Ask the secondary-school students to present their projects to each other, to get suggestions for improvements from the whole team. Remember to test the experiments with children of the target age beforehand, to estimate the required time. Up to seven younger children is a good group size. In our experience, each activity takes about 25-60 minutes, although we did not set a time limit.

The activities might take more time than expected, since children sometimes ask to repeat a section they particularly enjoyed. Keep in mind that young children enjoy being able to take small experiments home, or taking part in a small competition in which they can win prizes such as a jelly baby in an inflated balloon.

Especially when experimenting themselves, primary-school children had no trouble concentrating for up to two hours without a break. Before reorganising groups or starting a new experiment, hand out treats or drinks to mark the break.

And don't forget, if this is a new experience for everyone involved, there may be reservations on both sides (the kindergarten or primary school, and the secondary-school team). However, if you discuss potential issues during the preparatory phase, this should be easily overcome.

A number of projects have emerged in recent years to foster the curiosity of children in kindergarten and primary school. In 2001, we started one such initiative[w1] in Winnweiler, which has since been extended throughout Germany with the help of several sponsors. Together with Werner's secondary-school students from the Wilhelm Erb Gymnasium[w2] in Winnweiler, we developed physics teaching activities for children aged 4-10. With the secondary-school students as mentors, we went into kindergartens and primary schools and successfully ran experiments with the children on topics such as air, electricity, magnets, light, shadows, hearing, flotation and lightning.

A collection of teaching activities, experiences and background information has been published in a German-language brochure (THINK ING, 2007). Most of the experiments, as well as a general introduction to the project, are also available to be downloaded as English-language PDFs from the website of Science on Stage Germany[w3]. Below are step-by-step instructions for a set of experiments on hearing, suitable for both kindergarten and primary-school children. The online PDFs also contain further experiments from this section.

Attack on the eardrums

The aim is for the pupils to understand the function and importance of the ear, so that they will turn their MP3 players down to prevent damage to their auditory systems. On a journey from a sound source to the inner ear, sound production and the anatomy of the ear are explained.

Auditory walking tour

Get the pupils to take a walk through the grounds of the school or kindergarten, once with and once without earplugs, to experience the loss of environmental impressions when they partially 'switch off' their hearing. They will also learn about the dangers that (partially) deaf people are exposed to.

Do we really hear everything?

The human ear can perceive sounds with 20 to 20 000 oscillations per second. The number of oscillations per second is called the frequency. As we get older, we lose the ability to hear very high frequencies. Dogs can hear sounds with up to 35 000 oscillations per second (35 kHz), bats even higher-frequency sounds. Use a normal whistle and a dog whistle for the children to compare. Typically, a dog whistle is within the range of 16-22 kHz, with only the frequencies below 20 kHz audible to the human ear (and depending on the individual state of your hearing, you may not even hear these).

Adjust the volume of a signal generator with amplifier and loudspeaker to a medium level at an audible frequency. Then turn up the frequency to 50 kHz, and slowly tune it down from there. Ask the first child who can hear something to describe the sound (a high-pitched whistle).

Do our ears have favourite sounds? An individual auditory diagram

By testing our own hearing range, we can estimate the state of our hearing. Connect a signal generator with an oscilloscope and loudspeaker as indicated (see image below).

Using the signal generator, generate sounds between 250 and 16 000 Hz according to Table 1. To make the sounds comparable, make sure that they all generate a 'wave line' of equal 'height' on the oscilloscope.

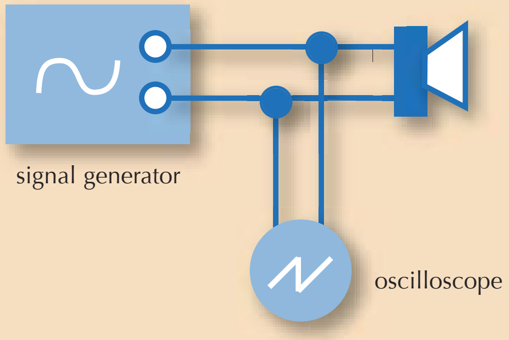
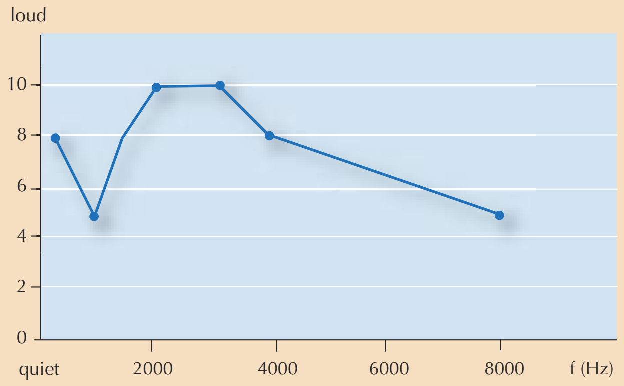


Image courtesy of Nicola Graf

How do you perceive the sound?	Sound 1	Sound 2	Sound 3	Sound 4	Sound 5	Sound 6	Sound 7
	16 000 Hz	8000 Hz	4000 Hz	2000 Hz	1000 Hz	500 Hz	250 Hz
very loud (10)							
loud (8)							
medium loud (5)							
quiet (3)							
very quiet (1)							

Table 1: individual auditory diagram



auditory diagram girl 8 years

Ask each child to complete the table (which can also be downloaded as a worksheet from the *Science in School* website[w4]), recording whether they experience each sound as being very loud, loud, medium loud, quiet or very quiet. This can be a little tricky. To make it easier, start with 16 000 Hz and do pairwise comparisons between neighbouring frequencies to be measured, i.e. 'How do you perceive the sound at 16 000 Hz? Now listen to the sound at 8000 Hz – how do you perceive it in comparison?' And so on. Typically, the human ear is most sensitive to the frequencies at which we usually speak (about 200–3500 Hz).

With the help of a secondary-school mentor (or teacher), each child should plot the perceived volume (e.g. loud = 8) against the frequency of the sound.

It is useful to make the same measurements with adults (e.g. teachers or parents) as well, because as we age, we hear high-pitched sounds less well. You may notice this when the TV is on – young children may hear a high-pitched whistling noise whereas adults do not.

How does sound reach the ear? The swinging candle

Because sounds are transported by variations in air pressure, sound moves air particles. The movement of a candle flame is used to illustrate this. Sound with a low frequency can even blow out a candle flame.

Materials

- A CD player with a bass loudspeaker playing techno music
- A candle and matches
- A paper funnel
- A (bass) drum with a hole in the back
- A signal generator with amplifier
- A loudspeaker suitable for low frequencies (at least as low as 100 Hz)
- Cables

Procedure

1. Place a burning candle in front of a CD player with a bass loudspeaker playing techno music. The flame will flicker in time with the music. If the effect is not very visible, use a paper funnel between the loudspeaker and the candle to enhance it.
2. Place the burning candle in front of the hole at the back of a drum. Beat the drum on the other side and watch the flame move or be blown out.
3. Using the cables, connect the loudspeaker to the signal generator and turn it to a low frequency (100 Hz). The candle will be blown out. To enhance the effect, you can use a paper funnel between the loudspeaker and the candle.

What happens in the ear?

Use a plastic or paper model (which may be homemade) of the ear to illustrate the different parts of the ear, which will be explained in the following experiments.

Images courtesy of Werner Stetzenbach

The outer ear: the auricle and eardrum

The auricle collects sound like a funnel. Use a paper funnel as an ear trumpet to improve hearing: whisper into it and see how it magnifies the sound.

The outer ear acts like an organ pipe that is closed at one end, so that the air in it can vibrate. This vibration is passed on to the eardrum, a membrane that behaves like a drum, and then through mechanical linkage to the three ossicles (small bones).


Image courtesy of Werner Stetzenbach

Materials

- A bass loudspeaker
- A signal generator with amplifier or a CD player with amplifier
- Cables
- Jelly babies

Procedure

Using the cables, connect the bass loudspeaker to the signal generator or CD player. Place some jelly babies on the speaker. Watch them 'dancing' with the vibrations of the loudspeaker membrane, which represents the eardrum.

The middle ear: the ossicles

Materials

- Two tambourines
- A drumstick
- A table tennis or styrofoam ball tied to a string
- A baking tray
- A wooden mallet or similar wooden instrument
- A bowl
- Aluminium foil or cling film
- Rice grains or sugar

Procedure

1. Hang the table tennis or styrofoam ball (representing the ossicles) in front of one of the tambourines, touching its surface (T2 in the image below). Beat the other tambourine (T1, the sound source) with the drumstick and watch the ball move, as the sound waves reach T2.

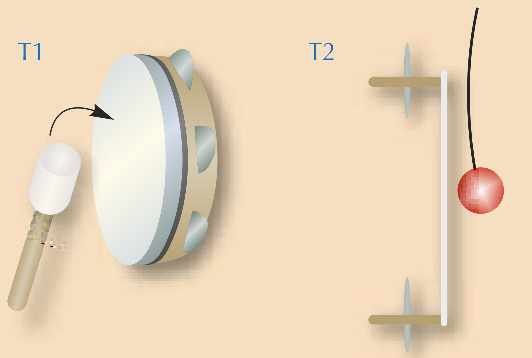


Image courtesy of Nicola Graf

2. Cover the bowl with foil or film pulled taut, and place rice grains or sugar on top. Hold the baking tray close, bang it with a mallet and watch the rice or sugar (representing the ossicles) jump.

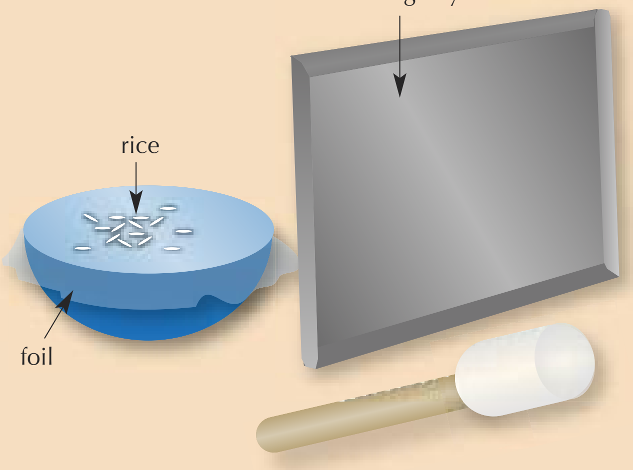


Image courtesy of Nicola Graf

The inner ear: the cochlea

There are auditory nerves in the hair cells of the cochlea. Sound (changes in air pressure) makes them move, which triggers information to be transmitted to the brain. The louder the sound, the more the hairs move. Very loud noises can even damage the hair cells.

A glass tube is used as a model for an uncoiled cochlea. Cork dust or talcum powder inside the tube represents the hair cells.

Materials

- A glass tube
- Cork dust or talcum powder
- Two stands (see image)
- A signal generator
- A loudspeaker
- Cables

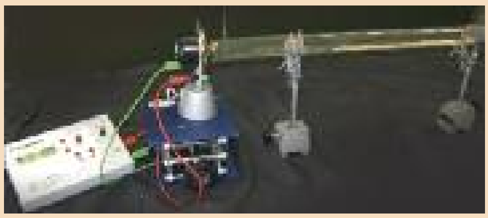


Image courtesy of Werner Stetzenbach

Procedure

Fill the bottom of the glass tube with cork dust or talcum powder and mount it horizontally on the stands.

Using the cables, connect the loudspeaker to the signal generator and place it in front of one opening of the glass tube.

Adjust the frequency of the sound (depending on the tube's length) until the tube resonates (for any given length, there are multiple frequencies at which it will resonate), making the dust vibrate visibly. This represents the movement of the hair cells.

Reference

THINK ING (2007) *Physik in Kindergarten und Grundschule II.* Köln, Germany: Deutscher Institutsverlag. ISBN: 9783602147816

Web references

w1 – To learn more about the Germany-wide *Physik in Kindergarten und Grundschule* project, see: www.think-ing.de/index.php?node=1218

w2 – For more information about the Wilhelm-Erb-Gymnasium Winnweiler, see: www.weg-winnweiler.de

w3 – To download the materials in English, see: www.science-on-stage.de/index.php?p=3_15&l=en

w4 –Table 1 can be downloaded as a Word document from the *Science in School* website: www.scienceinschool.org/repository/docs/issue14_kindergarten_worksheet.pdf

w5 – Science on Stage brings together science teachers from across Europe to share best practice in science teaching. Originating in 2000 as Physics on Stage, it was broadened in 2003 to cover all sciences. Science on Stage Germany organises many activities for teachers both in and outside Germany, and currently hosts the Science on Stage Europe office. For more information, see: www.science-on-stage.de

Resources

'Promenade 'round the Cochlea' is a regularly updated website providing background information and teaching suggestions on the auditory system. See: www.cochlea.org

Skidmore University, NY, USA, provides a useful collection of links for teaching the ear and the auditory system: www.skidmore.edu/~hfoley/Perc9.htm#teach

You can find a nice animation of the flow of sound waves through the ear here: www.sensory-systems.ethz.ch/Lectures/Auditory/Auditory_Animations_1.htm

The Howard Hughes Medical Institute website offers a report on recent research into our senses, including the quivering bundles that let us hear and how to locate a mouse by its sound. See: www.hhmi.org/senses

The Neuroscience for Kids website explains how our sense of hearing works, and includes some experiments and teaching materials: http://faculty.washington.edu/chudler/bigear.html

The 'How the Body Works' section of the About Kids Health (Trusted Answers from the Hospital for Sick Children) website has an explanation of the ear, including an interactive diagram of the auditory system. See: www.aboutkidshealth.ca or use the direct link http://tinyurl.com/yzzt5bv

The website of the US education research organisation SEDL offers online lesson plans for teaching the five senses. See: www.sedl.org/scimath/pasopartners

If you enjoyed this article, you might like to look at other teaching activities and articles suitable for primary school on the *Science in School* website. See: www.scienceinschool.org/primary

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Werner Stetzenbach has a physics degree and for the last 33 years has taught physics at secondary school. At the Wilhelm Erb Gymnasium, he is the head of sixth form (*Studiendirektor*) and the school specialist on didactic questions. He is part of the 'Physics in kindergarten and primary school' working group of Science on Stage Germany[w5] and has organised more than 25 training courses for educators and grammar-school teachers. He has also organised more than 50 workshops and training courses for physics teachers at secondary schools on the topic 'Physics in daily life: low-cost, high-tech hands-on experiments'.

Gabriele Stetzenbach is a medical assistant (*Arzthelferin*). Her role in the project was to make sure the experiments were appropriate for the target age and to help the secondary-school students with the practical setup. She also coordinated the collection of feedback on the project and played a major role in making sure the project would be expanded nationwide.

Image courtesy of Werner Stetzenbach