The Hearing of Sound - an Interdisciplinary Inquiry between Biology and Physics

Pupils investigating vibrations as the source of sound.

Summary:

The "Hearing of Sound" consists of 4 interdisciplinary (biology-physics) learning stations where pupils of age 14-15 can learn about sound and the ear by inquiry. Based on these experiences the learning materials and the questionnaires will undergo a cycle of improvement. In a second phase the "Hearing of Sound" will be deployed in a large number of classes. The measurements will be analysed and conclusions formulated.

Aims:

The aim is threefold:

(a) To foster interdisciplinary scientific thinking in order to connect disciplines which have been seen hitherto as separated ones. In 'the Hearing of Sound" the context of sound is the field where questions are raised that explore the field between biology and physics. Moreover, the context of music is added too and through this rather unexpected link students are invited to see natural science as a piece of culture too.

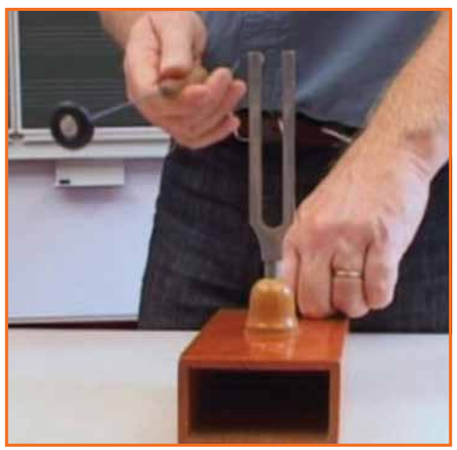
(b) To apply the pedagogy of Inquiry Based Science Education (IBSE) in concrete learning activities. Students are invited to:
   i. To wonder about sound and hearing.
   ii. To investigate the questions raised in the wondering (Learning at stations).
   iii. To confront their ideas and findings with scientific insights
   iv. To summarize their conclusions.

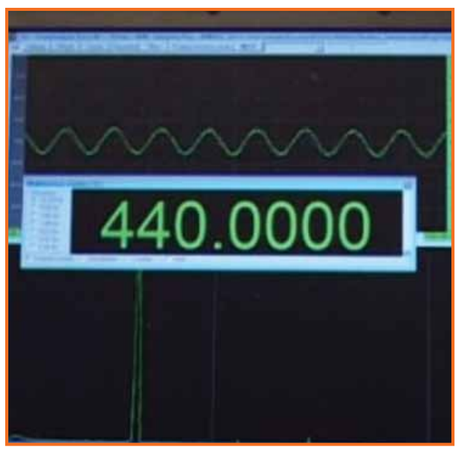
(c) To measure the effectiveness of the pedagogy of Inquiry in this concrete interdisciplinary case.

Main activities:

In this practice, the scientific inquiry is understood as a process of scientific reasoning along following lines:

1. Raise awareness of a phenomenon by giving a brief introduction. Make the students aware of what they do not know!
2. Let them form hypotheses in a cycle process from general ones to more specific ones
3. Let them test if the hypothesis can be proven by evidence by experimental inquiry
4. Guide them to develop consistent scientific explanations when analyzing the data obtained by the use of inquiry scientific thinking
5. Let them evaluate these explanations (metacognition): reflecting them further in the light of consistent scientific understanding that brings together all insights.





Experimental inquiry to explore the concept of tone and frequency of a tone with free sound analysing software

The Hearing of Sound - an Interdisciplinary Inquiry between Biology and Physics

Narrative:

The "Hearing of Sound" consists of 4 interdisciplinary (biology-physics) learning stations

1. **What is sound?**
   In station 1 pupils discover that vibrations are the source of sound. These vibrations are transmitted in waves through a medium (like e.g. the air). This brings up the question about a possible net-displacement of the air molecules in a wave. Pupils think about this by simple analogies like the Mexican wave. By measuring noise and tone by a free software tool and a simple micro connected to a computer, pupils discover that noise is called tone as soon as the wave repeats itself in time. From that moment on the notion of frequency makes sense. What we hear as higher and lower tones can be scientifically understood as the number of cycles per second.

2. **The anatomy of the ear**
   The investigation of the ear starts at the outer ear. By the ear flap and by the hearing canal the tympanic membrane is reached (middle ear). This raises the question of resonance. By an experiment with two tuning forks the pupils discover that vibration can be passed on to another object. It is the pressure of air molecules pushing on one side of the membrane that causes the membrane to vibrate. The Eustachian tube equals out the air pressure in the middle ear.
   In the middle of the tympanic membrane the first lever of the ossicles is fixed. The fact that the small ossicle collects the energy passed on by the larger ear drum causes an amplification. This is investigated in a little experiment with 'dancing rice'.

3. **Inner ear, sound quality and health**
   The real sensation of sound takes place in the inner ear: in the cochlea. It starts by giving further the amplified vibrations from the ossicles over the oval window to the liquid filled cochlea. It is noticed by a little experiment that a sound wave can travel in water as well. But how the sensation of hearing takes place? And how we can hear different frequencies? The crucial point is played here by the fine basilar membrane in the middle canal of the cochlea. It is tuned to different frequencies like different tuning forks. It is less flexible and narrower at the base than at the end where it is wider and more flexible. This means that the first parts do resonate at higher frequencies while lower frequencies are detected towards the end where resonance with higher frequencies occur. On top of the basilar membrane there are thousands of hair cells which can fire nerve pulses when they bend because of the vibration caused by the basilar membrane. The working of the cochlea is compared to a metallophone and a small experiment is done. Questions about Health are raised.

4. **What is music?**
   By the free sound analysis software the spectrum of different musical instruments is measured. Pupils discover that a tone consists of a row of harmonics which frequencies are integer multiples of the fundamental. In order to preserve the quality of hearing, the awareness grows not to expose the sensitive cochlea to too loud sounds.

Where pupils of age 14-15 can learn about sound and the ear by inquiry. In the project the effectiveness of the learning by inquiry are measured by pre- and post-questionnaires. In a first phase the "Hearing of Sound" will be tested in a few classes. Based on these experiences the learning materials and the questionnaires will undergo a cycle of improvement. In a second phase the "Hearing of Sound" will be deployed in a large number of classes. The measurements will be analysed and conclusions formulated.

End user:
The learning materials are meant for children of age 14-15 (1st year of 2nd stage/ 8th grade of secondary school)

Involved actors:
Biology, Physics or Music teachers of secondary schools

Location:
Classroom

Languages available:
Dutch, English, German

Where to find the application or case:
The information about the good practice "Hearing of Sound" is available on www.vakdidactiek.be/hearingofsound. The setups are stationed at KHLim Belgium and/ or UBT Germany.

Duration: The case lasts 5 lessons (a 60min) in class. They can be used in block or split up to subdivisions of one hour each.

Evaluation parameters:
Evaluation from teacher side: The Hearing of Sound will be evaluated by teachers who get to know the course during the Pathway workshops and professional developments, with questionnaires provided by the EUN, aiming for teachers' opinion and satisfactory level with the materials provided.
Evaluation from student side: The Hearing of Sound will be evaluated for the effectiveness of IBSE learning compared to learning in text based (classical) science lessons. Evaluated features will be mainly on the amount of Subject knowledge recalled after the course and after a retention, as well as the motivation of student towards science. A small scale analysis of the IBSE lessons has been performed in November 2011 in order to review the stations.

Connection with the curriculum: Belgium science curriculum: The ear is in the curriculum of biology for pupils of age 14-15 (1st year of 2nd stage of secondary school; Belgium)
German science curriculum: The topic of acoustics and senses is taught in class 7 in biology, class 6 in music, and class 7 in Physics of school type Realschule in Bavaria.

Teachers' Competencies

1	subject matter/content knowledge	x
2	nature of science	x
3	Multidisciplinary	x
4	knowledge of contemporary science	x
5	variety of (especially student-centred) instructional strategies	x
6	lifelong learning	
7	self-reflection	
8	teaching/ learning processes within the domain	x
9	using laboratories, experiments, projects	x
10	common sense knowledge and learning difficulties	x
11	use of ICTs	x
12	knowledge, planning and use of curricular materials	x
13	Information and Communication Technologies with Technological Pedagogical Content Knowledge	

Mapping best practices with main principles

PATHWAY

1. Building interest in natural science phenomena and explanations:

Sound and Music are phenomena that scientifically can be understood in terms of physics and biology. Although present in our everyday life sound - as an interdisciplinary reality - is in Belgium only covered in physics in the last year of secondary school. In biology on the other hand it is in the curriculum but the treatment tends to be more or less descriptive and poorly scientifically grounded. In this practice the pupils connect on an inquiry manner, the basic concepts of sound, both of physics and biology.

2. Building up informed citizens: Students understanding the nature of Science & Science in society:

The function of the cochlea, the organ that enables us to hear the rich spectra of sounds and voices, is still very unknown and still poorly estimated by the average citizen. Lots of people who regularly visit loud concerts or who are used to hear their music too loud sooner or later do loose at least part of their hearing spectrum. Even expensive medical treatment later on, can't give them back the full joy of hearing the timbre of music. Even the understanding of speech becomes a difficult task. Science is here once more in resonance with the quality of life.

3. Develop multiple goals:

- **understanding big ideas in science including ideas of science, and ideas about science**
- **scientific capabilities concerned with gathering and using evidence**
- **scientific attitudes**

The method of inquiry is at the forefront in this good practice: to foster a scientific attitude, to become wondered about the phenomena in nature, to raise questions, to build hypotheses and to look for evidence. Scientific thinking and reasoning is the learning goal in this interdisciplinary project. Basic scientific ideas are deeply connected into this project and brought to learners.

4. Understanding students' concepts and learning style about of science phenomena:

The pedagogical method of inquiry applied in the learning stations gives opportunities for learners of different learning styles. Wondering addresses the dreamers and fosters the desire for exploration. Looking for evidence and doing experiments addresses the doers and experimentators. Scientific reasoning and analysing addresses the thinkers. Drawing conclusions addresses the deciders and the planners.

5. Relevance of the content to daily life of students:

Sound is one of the main ways by which we communicate and express ourselves. The spectrum of sound, the timbre of music and voice opens a world of expression, art and beauty without which life is hardly imaginable. It is clear that the understanding of sound and hearing is a crucial point in gaining scientific literacy. Moreover the topic is at the basis for understanding other kinds of waves like water waves or electromagnetic waves which are all around us.

6. Understanding science as a process not as stable facts. Using up-to-date information of science and education:

The inquiry used in these 4 learning stations leads the pupils into a conceptual discovery tour in the world of sounds and music. By going to these stations, pupils do understand that new insights are always nearby: a next question and one further investigation away. In this manner the 'world of science' is brought into the classroom. Even just connecting the well-known school subjects like physics and biology give rise to deeper insights and give learners a broader and deeper sight on simple experiments. By this way science is experienced in this practice as no stable and closed book whatsoever but as a living invitation to join the scientific journey.

7. Activities for gaining knowledge, not for entertainment, nor for simple imitating of results:

The joy of finding out new connections is one of the basic motivations to do science. That is why it is better to give children space to wander around, to let them make mistakes and not to present science as a set of rules but as a quest and desire for knowing. The inquiry in these 4 learning stations gives them the pedagogical space to explore the world of sound.

8. Doing science: experimenting, analyzing, interpreting, redefining explanations:

In the learning stations pupils are given the opportunity to analyze the results of experiments themselves, scientific thinking is fostered and at the end, pupils are expected to draw his/her own conclusions. The pupil goes through the inquiry himself/herself and builds up gradually a growing scientific understanding of sound and hearing.

9. Assessment: formative ~ of students' learning and the summative ~ of their progress:

The design of the learning station themselves are such that there is formative guidance of the learners in every learning station. At the end pupils are asked to fill in a summary which helps them to stand back and look to the new insights they gained. At the end of the 5 lessons the learning outcome and motivational effect is measured through a summative questionnaire. The results of these questionnaires are compared to the results of a pre-test, and thus the progress can be measured.

10. Cooperation among teachers and with experts:

This practice is the result of a lasting corporation between the University of Bayreuth (Germany) and the KHLim teacher Education college in Hasselt (Belgium). Thus, teachers together with the researchers get the opportunity to learn about the pedagogy of interconnecting the sciences and the method of learning science by inquiry. Teachers of the participating schools are invited to a national congress where they interact with the researchers. These life interactions are sustained further over the website www.vakdidactiek.be/hearingofsound which contains a forum and shares the results of this practice. On a scientific level the results of this practice and of this educational research will be shared with the scientific community by articles in peer-reviewed journals and by talks on conferences of science education.