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PUPILS' (AGE 10 -13) CONCEPTIONS OF HEARING

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Abstract

The paper reports on an investigation into pupils' conceptions of hearing before they take part in teaching. This is the first step in the project 'Design and validation of a teaching sequence about sound, hearing and health' for pupils aged 10 -13. There are a number of studies of pupils' conceptions about acoustic phenomena, however very few take up the biological aspects of hearing. Pupils (92) have answered the question 'What happens with a sound that has reached your ear?' They were asked to explain their thinking by drawing in a figure, and then trying to explain their drawing in writing. In addition, 26 of the pupils were interviewed. The method of analysis involves identifying and coding components in the answers, such as the eardrum, parts of the middle and inner ear, nerves and brain, as well as causal chains. This detailed information was condensed into broader categories of description. It was shown that the majority of the pupils include the brain in the process of hearing even if they don't express any ideas of the structure of the ear and mechanisms of hearing. The design and validation of the teaching sequence comprise the Swedish part of the ISSUE-project (Integrating Subject Science Understanding in Europe) in Comenius 2.1 programme within the European community.

1. Introduction

High sound levels are more and more frequent in young people's lives and at the same time more and more people have impaired hearing conditions such as tinnitus. The problem is more serious among young people. The younger the child, the more sensitive s/he is to loud sounds. The National Swedish Board of Health and Welfare (Socialstyrelsen, 2003) reports that children between the ages of 13 and 14 are more affected by high sound levels than those between the ages of 18 and 20. They propose that precautions should be taken in order to maintain children's auditory health. There is a need for teaching at an early age, for example, during the first two years at school, to support children's possibilities of adopting an appropriate attitude towards high sound levels and environmental noise. An additional report (Socialstyrelsen, 2005) informs that every fifth twelve-year-old Swedish pupil have suffered or suffers from some form of tinnitus after having listened to loud music or loud sounds. Many children and young people listen everyday to walkmans like Mp3-players. Since they do not always use them carefully enough, the hearing organs are often exposed to unnecessary stress. According to WHO (Berglund, Lindvall, Schwela & Goh, 2000) the sound level of music that is listened to through ear-phones should not exceed 85 decibel(A).

In 2003 a part of the Swedish national evaluation of compulsory school was a project investigating pupils' problem solving skills (Kärrqvist & West, 2005). One

problem given to 12 year olds was called 'The disco dilemma'. It was about a disagreement about sound levels. Some pupils at a class disco wanted a very loud sound, others a more moderate one. How to solve the dilemma? In general the pupils viewed the problem within a 'democratic' frame – how to create justice and be fair to both groups? E.g. they proposed one room with very high sound level and one with moderate level, or changing between high and moderate level in the same room. They seldom questioned the aspect of health. Their problem-solving was not based on actual knowledge of the matter at issue, although part of the problem was a proposal to find out for themselves from various sources about risk of damaging their hearing. In short, pupils did not seem to value scientific knowledge as being particularly important when they had to make decisions about sound levels. The question is if they might have suggested other solutions if they had understood how the ear works and known about the sensitivity of the ear and the effects of sound levels.

Consequently, it is important that precautions are taken to make the children conscious of the harmful effect of high sound levels at an early age in order to maintain their auditory health. Our hypothesis is that an understanding of the mechanism behind the sound phenomenon and hearing process will make pupils more inclined to care for their hearing health. Thus teaching and learning is of great importance.

The question arises what methodology should be selected for this purpose. There is an increasing interest in Europe in 'Design and validation of teaching sequences' and the whole special number of International Journal of Science Education (Meheut & Psillos, 2004) has been devoted to this issue. Several groups in the world are now working with the development and improvement of this methodology, and we have adopted it for our work. Recently Andersson and Bach (2005) and Andersson and Wallin (2005), researchers in our group, have formulated some common steps in the design and validation of teaching sequences. According to these and other scientists, a prerequisite for the successful design of the teaching sequence and a good starting point is the profound knowledge regarding the pupils' conceptions of the subject taught.

Here we present an investigation of pupils' conceptions of hearing. It is the first part of a project concerning the design and validation of a teaching sequence about sound, hearing and health for pupils 10-13 years of age. This teaching sequence is a Swedish contribution to the European project (2004-2007) in Comenius 2.1-program with participants from six different countries.

2. Background

There are a fair number of studies of pupils' and students' conceptions and learning about sound and hearing. Most of them concern only sound generation and propagation, few take up the mechanism of hearing to understand, which requires the integration of several subjects. For example, Asoko, Leach and Scott (1991) found through interviews, that children and pupils between the ages of 4 and 16 lack a general idea about the origin of sound, namely that sound is created by vibrations of a material object. They point out that such an idea is very important for the understanding of sound. However, they did not inquire into the mechanism of sound propagation through the ear. Boyes and Stanisstreet (1991)

concluded in a study of pupils between the ages of 11-16 that teaching is more effective when you put it into a system that consists of source of the sound, the propagation of sound, ear, auditory nerve and brain. According to Driver, Squires, Rushworth and Wood-Robinsson (1994), it is only when pupils understand that sound is vibrations that they are able to understand the mechanism that governs hearing. To our knowledge Watt and Russel (1990) are the only researchers that provide explicit information about pupils' ideas of the process by which sound is perceived once it has entered the ear. The ear drum was mentioned by one-fifth of the upper juniors, age 9-11 (n=84), and one-tenth of lower juniors, age 7-9 (n=74). Some of these children mentioned vibrations set up in the eardrum. One pupil described bones within the ear. The apparatus contained within the inner ear to translate sound vibrations into neural impulses which travel to the brain was not mentioned in detail by any child. The brain was mentioned by one-tenth of lower and upper juniors.

3. Research questions

The overall aim of the project is to find out to what extent a carefully designed teaching-learning sequence might improve pupils' understanding of the properties of sound, the function of the ear and hearing and acoustic conditions that might cause damage. The study presented in this paper tries to make a contribution to this overall aim by answering the question:

What are10 -13-years-old pupils’ conceptions of hearing?

4. Methodology

General methodology of the project

As indicated in the introduction, we use a methodology that is called 'Design and validation of teaching sequences'. Major steps in the work are:

1. Didactic analysis of the content of the teaching and research findings about pupils’ conceptions of sound and hearing.
2. Design of a teaching sequence that is tested on a small scale. The sequence is gradually revised.
3. Teachers carrying out teaching in ordinary classes.

As part of our work relating to the first point, we probed, the pupils’ conceptions of sound, hearing, sound-levels and ideas of hearing-health before the teaching started. The teachers participating in our project distributed ten paper-and-pencil questions to the whole class and explained their need to learn what the pupils already knew about sound and hearing in order to plan further work. Most of the questions were in a multiple-choice format, followed by an invitation to the pupil to explain his/her choice. There was no time limit for doing this diagnostic pre-test.

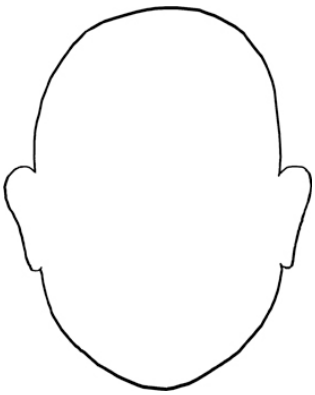
The pupils

Pupils from a middle class school in a city on the west coast of Sweden are participating in the study. The children have not previously met any formal

teaching about hearing and the anatomy of the ear. There are 92 pupils, 47 within the age of 10-11 years and 45 within the age of 12-13 years.

The present study

This paper deals with how the pupils answer one open-ended question on the diagnostic pre-test, namely ’What happens to a sound that has reached the ear?’ They were asked to explain their thinking by drawing in a figure, showing the contour of a head 'en face', including the outer ears, and then trying to explain their drawing in writing (figure 1).



HOW DO WE HEAR?

What happens to a sound that has reached the ear? Draw what you think right now.

Write a short text to the picture that can explain how you were thinking when you were drawing.

Figure 1. Test question used in the study

In addition, 27 pupils were interviewed about what was in their minds when they were answering the paper-and-pencil questions. There was a selection of pupils from different ability levels, from different age-groups and a balanced distribution of girls and boys. The purpose was to test the validity of the diagnostic pre-test. The interviews, about 15 minutes, were performed with one pupil at time and recorded with the permission of parents and pupils. The researcher and the pupil looked through the pupil's written answers and s/he was asked to explain what the question was about. Besides, the pupil was asked to tell how s/he was thinking when trying to explain something in her/his own words. With reference to the actual questions the same procedure was used concerning both the text and the drawing. The researcher was an active listener and, if needed asked for further clarifications, but no new questions were introduced.

5. Analysis

The analysis was based on both the written answers and drawings. The drawings and the explanations were sorted and arranged in a ranked order that reflected different levels of understanding the mechanism of hearing. Finally, we invented five components that we could use to describe the pupils' answers. Either a certain answer corresponds to just one of these components, or is a combination of two or more of them. The components are as follows (A – E):

Inclusion of the inner part/parts of the ear

Answers and/or drawings include one or more part/parts of the middle or the inner ear.

A. Signs of anatomical structures

Answers that describe one or more part/parts of the middle and/or inner-ear. This category also includes answers or drawings where pupils clearly point out part/parts without mentioning the name of the part or putting the wrong name of the part.

'*The sound comes into the ear into the eardrum which alarms the brain*'. The pupil draws how a signal from a telephone passes through the eardrum and then proceeds to the brain.

'The sound comes into the ear and then it goes through the stable, and then the saddle and through the eardrum and the cochlea and then the sound is in contact with the brain'. There is a detailed drawing of all parts.

'The sound goes into the ear and reaches the eardrum and thereafter the ear bone and is caught'.

B. Signs of transformation inside the ear from sound into impulses

Answers with an explicit idea of a mechanism where sound, described as 'vibrations', 'sound waves' etc. transforms into something else inside the ear that might be 'signals', 'sent through nerves' and the like. There are some simple explanations that give expressions of this mechanism, and even if they do not use the correct scientific words they are categorized here.

'The sound goes to the eardrum, which sends signals to the brain'.

'The sound comes to your eardrum, which makes three small bones knock together then this is sent through nerves to your brain'.

Inclusion of the brain in hearing

Answers and/or drawings that include the brain in hearing.

C. Involvement of the brain in hearing

Answers where pupils draw or explain that the brain is involved in hearing. The brain is described in the sense of an anatomical structure or as a receiver.

'*The sound goes into the brain and then it disappears*'.

'*There are signals coming into the brain*'.

The most complicated answer at this level is:

'The sound comes to the brain which says what you have heard'.

D. Signs of perception in the brain

Answers with explanations that indicate a process of perception in the brain. By this we mean that something is happening when a 'sound', a 'signal', a 'vibration' and so on reaches the brain. The answers clearly indicate something more than just hearing when the brain is involved.

'*The sound goes into the head to a place that tells the brain that someone is saying something. That place also says what voice the sound says'.*

'The sound is captured by the ears and they send it further to the brain, which explains what you have heard'. This quotation also is illustrated by the pupil's drawing (figure 2):

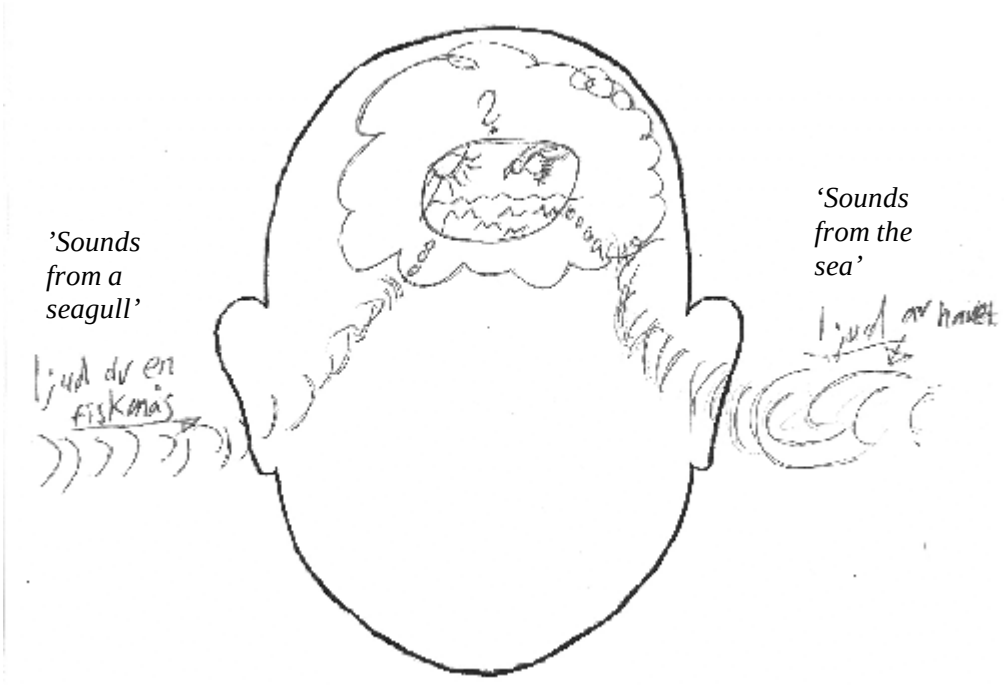


Figure 2. A seagull flying over the sea is drawn in the brain.

E. No answers and other answers that do not deal with hearing.

Two of researchers then separately and independently scored all the drawings and the explanations that went with them. We agreed on 84 % of scorings. In cases where our views differed, we discussed each case until we agreed. The differences were mostly about the interpretation of components B and D.

6. Results

Components

All coded components are compiled into a table (table 1) that gives an overview of the results.

Table 1. How do we hear? Number of components in pupils' explanations (including drawings).

Components	Age		Total n=92
	10-11 n=47	12-13 n=45	
A. anatomical structures	9	17	26
B. transf. sound-impulses	3	3	6
C. brain involved	29	30	59
D. perception in brain	2	1	3
E. no answer/others	14	10	24

Nearly two-thirds of the total numbers of pupils involve the brain in hearing (C). One quarter mention/draw parts of the middle and/or inner ear (A), but there is a difference between the different ages. Twice as many of the older pupils are

aware of parts inside the ear. Not so many pupils have any idea about the transformation of sound inside the ear into something else like a signal or the like (B). Three pupils show signs of understanding the perception of signals in the brain (D).

Whole answers

There are answers that can be described by just one of the four components. Other answers involve two or more components. This reflects going from a simple to more and more advanced answer. The different categories of answers that we have found are presented in table 2.

Table 2. How do we hear? Distribution by categories of number of' answers.

Categories	Age		Total n=92
	10-11 n=47	12-13 n=45	
A only	3	3	6
C only	23	17	40
A + B	1	2	3
A + C	3	11	14
C + D	1	1	2
A + B + C	1	1	2
A + B + C + D	1	0	1

A little less than 50% of the total numbers of answers only involve one component and then it is mostly that the brain is involved in hearing (C only). It is likely that pupils in this category do not have any ideas yet of the importance of the inner parts of the ear. A typical drawing consists of a line from the outer ear to some form of a brain (figure 3).

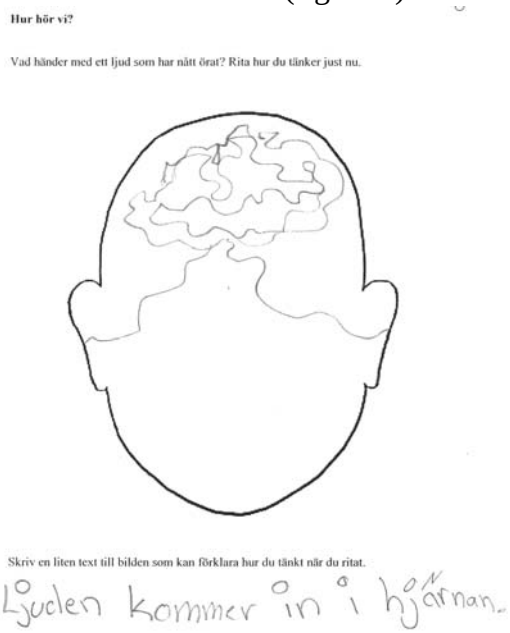


Figure 3. This drawing shows the connection between the ear and the brain. Consequently the pupil means that the sound comes through the ear. The text written by the pupil is in English: *'The sounds come into the brain'.*

In consequence the older pupils are more often aware of the link between the inner parts of ear and the brain than the younger ones (A+C). There is an example of this (figure 4).

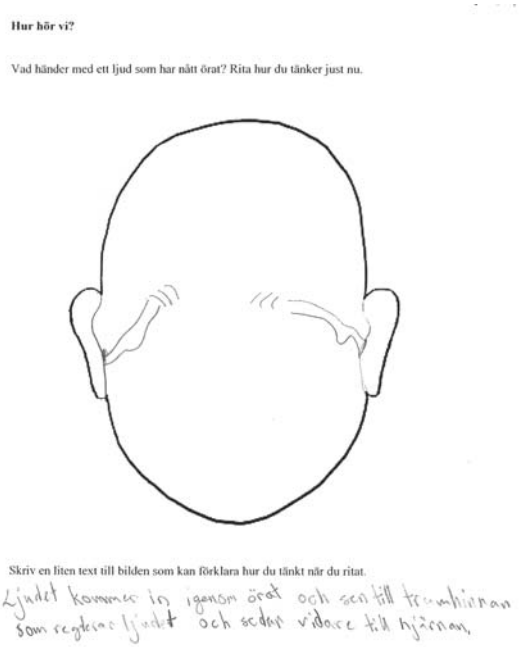


Figure 4. *'The sound is coming through the ear and then to the eardrum that regulates the sound and then it goes further on to the brain'*. The drawing concerns the eardrum, but the text also describes the connection with the brain.

There are a few pupils who also connect the brain to perception (C+D).
About 10 % did not mention the brain at all; they only think of parts of the ear (A only) or go a little bit further and show signs of understanding sound transformation (A+B). You can say that, according to their answers, hearing ends up in the ear. There are three answers that indicate a rather good understanding. Two of them shows a causal chain including parts inside the ear, transformation of the sound inside the ear and a signal or the like that move to the brain (A+B+C). The third one, from a boy 11 years old, includes also the implication of perception in the brain (A+B+C+D):
'The sound/vibrations goes into the ear and then to the small bones and then the vibrations go through the cochlea which sends a signal up to the brain and then the brain finds out what the other person says'.

Anatomical structures
Those drawings/explanations that include part/parts of the middle and/or inner-ear most often mention the eardrum. Other parts are mentioned too. See table 3 for an overview.

Table 3. Number of different anatomical structures in the middle and/or inner-ear in the drawings and/or the writings of pupils.

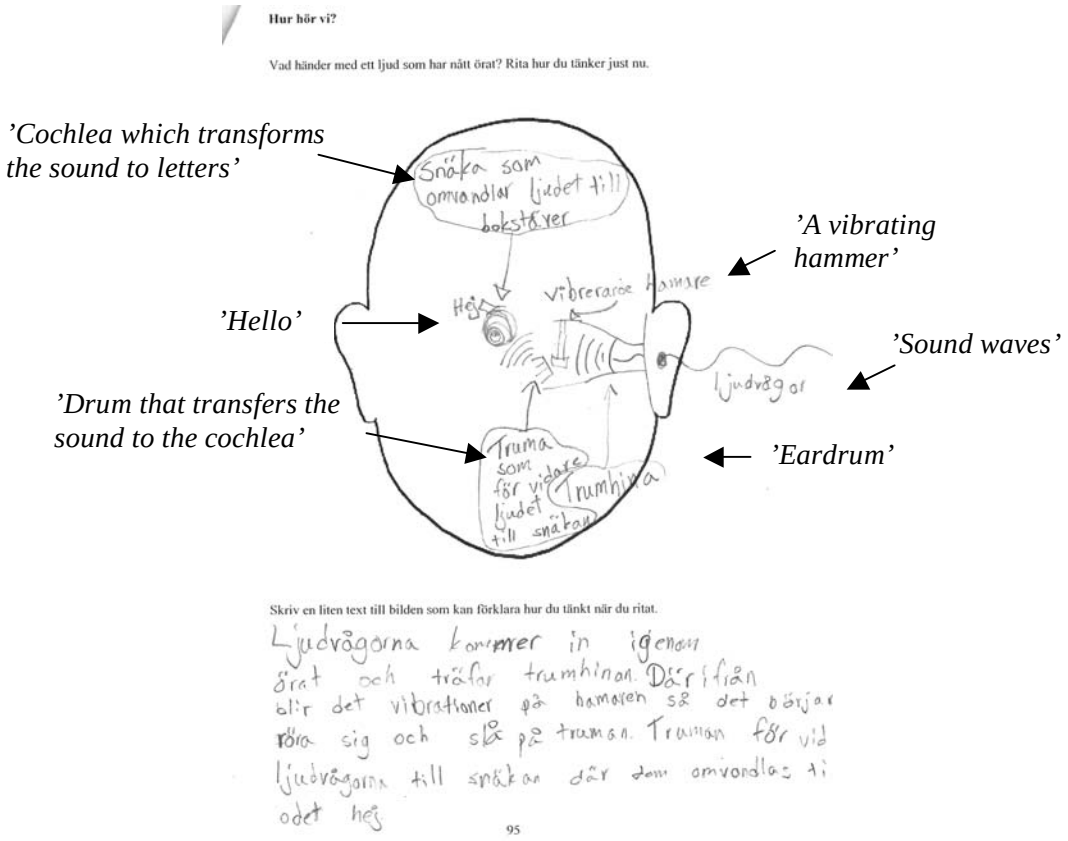
Anatomic structure	Age		Total n=92
	10-11 n=47	12-13 n=45	
Eardrum	7	15	23
Ossicles generally	5	0	5
Malleus	2	2	4
Incus	0	0	0
Stapes	0	0	0
Everyday meaning of ossicles	0	5	5
Cochlea	2	9	11

A quarter of all the pupils are conscious of the eardrum, and of these there are twice as many the age group 12-13 years. About 10 % in both groups include parts of the middle ear. However, there is some confusion about terminology. In Swedish schools, the terms malleus, incus and stapes are not used. Instead, the Swedish words corresponding to hammer, anvil and stirrup are common parlance. This probably explains why some describe as a malleus hammer and why some others claim that there is a saddle and a stable in the inner part of the ear. One pupil describes how the malleus hits a drum. These answers are categorized as 'everyday meaning'.

There are 11 %, in the whole in the older group who are aware of the cochlea. No one mentions the sensory cells of the cochlea, the hair cells, though there might be one pupil that is possibly aware of them. It is a question of interpretation. '*There is a lot of hearing things and if somebody screams very loud it might happen that a thing is destroyed'!* One pupil uses the term nerve for the connection between the ear and the brain. There are other words for this connection like: 'flex', 'the sound goes', 'signal' and 'sound waves'. Most pupils show the connection in their drawings by different illustrations, the most common being simply a line.

There are pupils who mention two or more parts and as a result they are counted for each structure in table 3. We will illustrate this by a drawing (figure 5).

Figure 5. An example of a pupil who is aware of parts in the middle- and inner-ear, even though there are expressions of some structures by means of words in an everyday meaning. This pupil does not include the brain in hearing.



'The sound waves come into the ear and come up to the eardrum. From there they turn into vibrations that hit the hammer and then the hammer begins to move and hits the drum. The drum moves the sound waves further on to the cochlea where they are transformed into the word hello'

Three pupils say that there is a 'sound' or 'signal' back to the ear. This is true as a matter of fact, as there are electric signals from the brain to small muscles inside the middle ear and besides there are some signals to the membranes with the hair cells in the cochlea. However most signals go from the ear to the brain.

Interviews

The interviews showed that 20 pupils of 26 (77 %) used exactly the same components as in their drawings and written explanations from the beginning. Three of the pupils, who showed no ideas of hearing in the pre-test, expressed during the interview that they in fact where aware of the brain in hearing. Two pupils, who initially only mentioned the brain, explained later that there were also structures in the ear that were important. One pupil started with structures in the ear, but in the interview he also added the brain.

We conclude that most likely three quarters of all pupils show a valid picture of their preconceptions concerning hearing and the mechanism of hearing at the paper and pencil occasion. The rest probably knows more than we can see in their pre-tests.

7. Discussion

The problem-solving part of the national evaluation 2003 (Kärrqvist & West, 2005) showed that pupils aged 11-12 generally do not take scientific knowledge into consideration when they have to make a decision about the sound level at a disco. A prerequisite for using scientific knowledge in this context bring into focus that the pupils have had an opportunity to learn something about sound, hearing and how to protect their own and others hearing health. Socialstyrelsen (2003, 2005) point out the problem of tinnitus among young people, and they propose teaching at an early age. The results of this study direct our attention to some key ideas of teaching. To support the pupils' conceptions of hearing, there is a need for an understanding of the connecting link of sound from outside through the ear and further to the brain. How can you understand why you should adopt a cautious attitude if you do not know there are structures inside the ear that you have to look after? A little less than 50 % of the pupils in this study did not involve the inner parts of the ear in hearing, although they mentioned the brain. More pupils mention the brain in this study than reported by Watt and Russel (1990), who showed that about 10% of the pupils included the brain. A quarter of the pupils are conscious of the eardrum, and of these there are twice as many in the age group 12-13 years. About 10 % include parts of the middle ear. These results have the scorings somewhat higher then the study of Watt and Russel. There is no need for detailed knowledge of all anatomical structures, including their names, even though discussion of the terminology might be fruitful. Function is set before detailed knowledge.

None of the pupils mention the sensory cells in the cochlea. We believe that pupils who have learned that there are sensitive hearing receptors, hair cells, inside the inner-ear might improve their awareness of hearing health. This part of the ear is crucial in issues of tinnitus, since the transformation of sound from vibrations into neural impulses occurs in these cells. It is important to have an idea of how vibrations from loud sounds are related to the risk of damage to the hair cells. Another significant piece of information is the fact that damage might occur without a feeling of pain. We do not mean that the teacher should discuss all this at an advanced level at these ages, as explaining the structure of cells or how neural impulses function. However, we regard understanding of the function of the ear as one important contribution to supporting the pupils' care for their own and other's hearing health.

It might interest the pupils to include perception in the brain when learning about hearing. Very few pupils in our study are aware of this mechanism, they rather think of the brain as a reciever. The perception has in itself a subordinate importance compared to the understanding of hair-cells to prevent tinnitus. We also believe like Asoko et al. (1991), Boyes and Stanisstreet (1991) and Driver et al. (1994), that there is a need for pupils to learn about sound in the physical sense to be able to understand the mechanism that governs hearing, e.g. that sound is vibrations of matter and that these vibrations propagate through the air and into the ear. The question of sound levels, and thereby the teaching of hearing, is in consequence a question of integration of different school subjects, but it is also a question of science for all and scientific literacy. In Sweden teaching about the ear

and hearing is generally separated from teaching about sound and sound propagation.

Our Teaching Learning Sequence integrates school subjects such as biology, physics and chemistry. Other subjects can also be included, for instance, music and technology. We believe that such integration into the field of sound, hearing and health is necessary in order to create a holistic picture. Our sequence is an example of applying a humanistic perspective in science education (Aikenhead, 2006). Aikenhead includes such parts as citizenship preparation for the everyday world and moral reasoning integrated with values, human concerns and scientific reasoning.

The area of hearing health is an urgent societal issue, and the work at school must also comprise discussions of high sound levels and the pupils' values within this area. If the pupils are given the opportunity to do this, we think their awareness of their own and other's auditory health will increase, as well as their inclination to take protective action when needed. Further studies will report on children's learning within the area as well as their attitudes to high sound levels before and after teaching.

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