Summary

Teaching and learning science in compulsory school

Students’ learning in relation to a research-based teaching of sound, hearing and health

Introduction
The overall aim of the research project was to examine to what extent a research-based teaching-learning sequence (TLS) might improve students’ (aged 10-14) understanding of the properties of sound, the function of the ear and hearing, and how to maintain auditory health. Taking students’ preconceptions as a starting point a TLS was designed and elaborated in the form of a flexible Teachers’ Guide (West, 2008). This guide was also regarded as an instrument for teachers’ further knowledge building.

Teachers made use of the TLS as a resource material and as a basis for their planning of lessons. Students were given a pre-, a post- and a delayed post-test one year after the teaching intervention. The students’ answers in these tests were used and carefully analysed from the different frameworks developed. The results gave insights into those learning and teaching demands that constitutes challenges to students as well as to teachers, when beginning to learn, or to teach sound, hearing and health. The combined results from these analyses are summarized into a domain specific hypothesis for teaching.

Theoretical framework
The primary goal of science education is to offer all young people an education in and about science, including producing the next generation of scientists. The aim is to develop an ‘understanding both of the canon of scientific knowledge and of how science functions’ (Osborne
Learning school science involves learning about a world consisting of matter and energy, and every learner has to actively construct an image of the world by her/himself from what she/he already knows (Piaget, 1954). Thus, the ‘real’ world is always the experiential world. A consequence of Piaget’s ideas is that the learner’s starting point becomes important. Piaget also stated that the individual needs to construct her/his ideas in interaction, especially linguistic interaction, with other people. The active role of learners is what Vygotsky (1978) emphasized, and he stressed the importance of interaction and guidance from persons knowing more; this interaction taking place in the zone of proximal development, ZDP. The importance of social interaction with peers in the individual’s learning is also stressed by many other researchers (e.g., Barnes & Todd, 1977; Lemke, 1998; Mercer, Daws, Wegerif & Sams, 2004; Treagust, Jacobowitz, Gallagher & Parker, 2001).

When interacting with others, language operates as an epistemological tool in constructing science understanding (Hand & Prain, 2006). Norris and Phillips (2003) argued that without the verbal, visual, mathematical and gestural languages of science there is no science. The discourse of everyday social language is developed by experiences and talk in social settings, whereas learning school science involves learning the scientific-social language that has been developed in the scientific community (Amettler, Leach & Scott, 2007; Mortimer & Scott, 2003; Scott, Asoko & Leach, 2007). But as school science differs from science in the scientific community, it is more relevant to talk about school-science-social language (Amettler et al., 2007). Consequently, learning involves making sense of this language and relating it to previous ideas, reorganizing and reconstructing these ideas in a new discourse. This process of learning is personal as well as social, and the teacher’s role in mediating the school-science-social language for students is crucial (Leach & Scott, 2002; Scott et al., 2007). Science classrooms can be regarded as communities of discursive practices where students are engaged and socialized into that particular community of knowledge (Carlsen, 2007; Driver, Asoko, Leach, Mortimer & Scott, 1994).

Not only language but also other representations are important for learning science (Lemke, 2003; Norris & Phillips, 2003; Prain, Tytler & Peterson, 2010). Prain et al. place major emphasis on the importance of using representations in science learning in that ‘negotiating representational meaning encourages the students to consider both the adequacy of their representation to their current ideas, as well as the adequacy of the representation to the phenomena they are attempting to explain’ (p. 805).

In addition, some more perspectives of students’ learning will be mentioned. Firstly, researchers emphasize developing students’ competence in constructing arguments on the basis of scientific knowledge (Osborne, Erduran & Simon, 2004). Secondly, the power of formative assessment; in their extensive review of formative assessment, Black and Wiliam (1998a, 1998b) pointed to the fact that formative assessment improves the students’ motivation, self-confidence and learning. In doing this, there is also a need for clear goals for learning (Millar, Leach, Osborne & Ratcliffe, 2006). Finally, one more important factor for students’ motivation is that teaching and learning school science must reflect students’ personal values and ideals concerning contemporary youth and their culture (Osborne & Dillon, 2008), which has been a problem, particularly in school physics (Schreiner & Sjøberg, 2007, Skolinspektionen, 2010). Therefore, considerations concerning the students’ motivational and affective processes will stimulate them to be active and have intentions to learn when constructing their knowledge in interaction with others (Treagust & Duit, 2008).
In today’s youth culture, listening to music and often listening to high sound levels is common among many young people in such settings as concerts, discos and in the use of personal music players (Chung, Des Roches, Meunier & Eavey, 2005; EU, 2009; Vogel, Brug, van der Ploeg & Raat, 2007, 2010; Vogel, Verschuure, van der Ploeg, Brug & Raat, 2009). For this reason, an important everyday issue is awareness of how to deal with loud sounds which includes learning about sound, hearing and how to maintain auditory health. Connecting teaching about sound to students’ everyday life and health issues might stimulate their interest in learning about sound (Jenkins, 2006; Schreiner & Sjøberg, 2007).

The research questions

The research questions contribute to answering the overall aim, i.e. examining to what extent a research-based teaching-learning sequence might improve students’ understanding of sound, hearing, and auditory health, by addressing the following issues:

- What are 10 to 14-year old students’ understandings of sound and sound transmission before and after a research-based teaching intervention about sound, hearing and auditory health?

- To what extent do students use a generalized theory about sound and sound transmission in their understandings before and after the intervention?

- What are the students’ understandings of hearing and tinnitus before and after the intervention?

- What are the students’ standpoints on loud sounds, auditory health and use of hearing-protection devices before and after the intervention?

- What are the implications of the obtained research results for future teaching about sound and hearing?

- How can a subject domain specific hypothesis be formulated that is valid for teaching about sound, hearing and health?

Research design

The educational design used in this study is derived from traditions within design research, which has been a continuous endeavour since the classical article about design experiments by Brown (1992). Brown’s research focused on the theory-practice gap, which was also what Linjse (2000) emphasized in order to develop content-specific didactic knowledge. There are other examples of approaches to design-based research (Kattman, Duit, Gropengieber & Komorek, 1996; Leach & Scott, 2002; Lijnse, 1994, 1995; Kelly, 2003; Méheut & Psillos, 2004; Tiberghien, 2000), and the design used in this study is based on Design and Validation of Teaching-Learning Sequences (Andersson & Bach, 2005; Andersson, Bach, Hagman, Olander & Wallin, 2005; Andersson & Wallin, 2006). According to this framework there are some general theoretical considerations regarding students’ learning. Firstly, the framework is based on a constructivist view of the
learner. Secondly, the teacher is considered as the bearer of the scientific knowledge and is well acquainted with common alternative ideas of the teaching content. The teacher’s introduction of concepts and systematic planning of situations for the use of concepts is crucial. Thirdly, students should be given opportunities to conceptualize the school scientific content by means of talking and writing science, individual and group reports, true dialogue, cross-discussion and small-group work. Moreover, the framework emphasizes formative assessment that should be done consciously and systematically. Finally, considerations concerning students’ interest and motivation are of importance. These general guidelines are combined with aspects about the nature of science limited to school science and content-specific aspects limited to the given topic.

On the basis of the presented framework a research-based teaching-learning sequence was designed for the school scientific area of sound, hearing and auditory health. The sequence was elaborated in the form of a flexible Teachers’ Guide, and it was regarded as an instrument for teachers’ further knowledge building. Teachers, with students from grade 2-9, made use of the guide as a tool for designing their own lessons, selecting goals and choosing activities and problems for students to solve. In this way the TLS was tested, results from practice were collected and evaluated, the teachers’ guide was refined and this process was repeated several times. The results in this study are based on research from the final cycle.

Briefly, the guide used by the teachers in this study, dealt with the following content: auditory health and attitudes; sound and hearing throughout history; matter and a particle model for matter; sound and sound transmission; the function of the ear and hearing; animals, sound and hearing; students’ conceptions about sound and hearing including previous research; national curricula and syllabuses; ideas for teaching goals; formative assessment; suggestions for teaching and finally an appendix consisting of resource-materials for copying (West, 2008).

Methods and data
The approach was to explore the students’ conceptions and learning about sound, hearing and auditory health including the students’ standpoints to loud sounds when teachers implemented the TLS in practice. Seven teachers from four schools and their 199 students from grade 4, 7 and 8 participated in the study. The teachers continuously documented their lessons in diaries on an Internet platform where a lot of collaboration took place; teachers discussed and gave feedback to each other. I also took part in these discussions. I visited a selection of lessons, observed the lessons and wrote extensive field notes. The data from the teachers’ diaries, students’ notebooks and notes from my visits were used as sources to get a reliable picture of the intervention in the different classrooms. In addition, the teachers were individually interviewed before and after the intervention.

The teachers designed their own intervention by formulating goals for students’ learning in accordance with the national curricula using the ideas and proposals in the Teachers’ Guide (West, 2008). These goals guided the content of the lessons, but depending on the individual teacher and the students’ questions they were treated at somewhat different depth. The total time used for the teaching intervention about sound, hearing and auditory health was around 15-20 hours.

Students were given pre-, post- and a delayed post-tests one year after the teaching intervention. On each occasion, there was a questionnaire dealing with students’ standpoints on loud sounds, experiences of tinnitus and listening behaviour to headphones, and a test with questions related to the school scientific learning goals.
Summary of the studies

Study I

The aim of this study was to explore students’ learning about hearing and tinnitus in connection with the teaching intervention. In pre-, post- and delayed post-tests, students were asked to use drawing and writing to express their answer to the question ‘What happens to a sound that has reached your ear?’ A questionnaire concerning tinnitus, experiences of tinnitus and listening behaviour was also given. The results show that approximately one quarter of students in grade 4, and half of students in grade 7 and 8 daily listen/almost daily listen to music in their personal music players. About 35% to 70% answered they had experiences of tinnitus and 5% reported they were often bothered by tinnitus. In the pre-test a majority of students in grade 4 and 7 answered that a sound goes to the brain or they did not answer anything at all when they were asked to describe what happens to a sound that has reached the ear. These descriptions/drawings did not indicate awareness of any structures in the ear. The most common answer in grade 8 embraced the brain as well as some part of the ear. The results show that the students’ knowledge of hearing and tinnitus had increased after the intervention and that this knowledge was well retained one year later. The students in grade 4 learned just as much as the older students, although it was more difficult for them to understand cell structures and causal chains. To conclude, students are capable of learning about hearing and tinnitus already at the ages of 10-11. Knowledge of hearing and tinnitus may be an important prerequisite for conceptualizing the risk of being exposed to loud sounds. No systematic gender differences were found in the results.

Study II

The aim of this study was to explore students’ learning of sound. Learning abstract concepts such as sound often involves an ontological shift since to conceptualize sound transmission as a process of motion demands abandoning sound transmission as a transfer of matter (Carey, 1991; Chi, Slotta & De Leeuw, 1994; Reiner, Slotta, Chi and Resnick, 2000). Thus, for students to be able to grasp and use a generalized model of sound transmission poses great challenges for them. The students’ views about sound transmission were investigated before and after teaching by comparing their written answers about sound transfer in different media/no media: air, water, wood and vacuum. The analysis involved interpreting students’ underlying theories of sound transmission, including the different conceptual categories that were found in their answers. The results indicated a shift in students’ understandings from the use of a theory of matter before the intervention to embracing a theory of process afterwards. The described pattern was found in all groups of students irrespective of age. Thus, teaching about sound and sound transmission is
fruitful already at the ages of 10-11. However, the older the students, the more advanced is their understanding of the process of motion. In conclusion, the use of a TLS about sound, hearing and auditory health promotes students’ conceptualization of sound transmission as a process in all grades. The results also imply some crucial points in teaching and learning about the scientific content of sound. No systematic gender differences were found in the results.

Study III
West, E. (manuscript). Learning for everyday life: Students’ standpoints on loud sounds and use of hearing protectors before and after a teaching-learning intervention.

Researchers have highlighted the increasing problem with loud sounds among young people in leisure-time environments, recently even emphasizing portable music players, according to the risk of getting hearing impairments such as tinnitus. However, there is a lack of studies investigating compulsory-school students’ standpoints and explanations in connection to teaching interventions integrating school-subjects content with auditory health. This study explores students’ standpoints on loud sounds including their standpoints on use of hearing-protection devices before and after the teaching intervention. The results show that the students make healthier choices in questions of loud sounds after the intervention, and especially among the older ones this result remains or are further improved one year later. There are also signs of positive behavioural change in relation to loud sounds. Significant gender differences are found; generally the girls show more healthy standpoints and expressions than boys do. If this can be considered to be an outcome of students’ improved and integrated knowing about sound, hearing and health, then this emphasizes the importance of integrating health issues into the ordinary school science.

Study IV – the book chapter

The aim of this chapter was to account for a general overview and implications of the results from my research, including examples of the teachers’ experiences according to the intervention, and results from The National Evaluation of the Swedish Compulsory School (Kärrqvist & West, 2005). In the chapter there is a discussion of teaching and learning about the origin of sound, sound transmission in different media and what happens when a sound reaches the ear and is transmitted through the auditory organ. These form the basis of ideas of how to promote auditory health within school and school-science. There are possible goals and activities for this teaching, including research results about students’ preconceptions of sound, hearing and auditory health. According to teachers’ and students’ experiences from the intervention there are examples that illustrate the impact of formative assessment on teaching and learning. The teachers also experienced that their wording and use of concepts in the classroom were visible in their own students’ written answers when comparing students’ answers from different classes. Thus the chapter touches on the theory-practice gap of teaching and learning within the whole area of sound, hearing and health.
Overall results, discussion and conclusions

The overall results are summarized into a domain specific theory for teaching about sound, hearing and auditory health. Moreover the results are discussed in relation to the students’ age and gender and the teachers’ experiences are summarized. Finally, there is a discussion of the limitations of the present study.

Domain specific hypothesis

The combined results from the studies are summarized into a domain specific hypothesis for teaching. It consists of three different aspects:

1. content specific aspects, which are unique for every field of science,
2. aspects concerning the nature of science, and
3. general aspects.

The hypothesis can be tested in new design experiments, and if it will withstand future tests it can be developed into a domain specific theory for teaching about sound, hearing and auditory health.

A. Content specific aspects

Sound

If the following content specific aspects are considered in teaching, the students’ opportunity to learn and understand the theory of sound and sound transmission will be improved:

1. Concrete experiences of air, phases, phase changes etc.
2. A particle theory for the gaseous state.
3. A particle theory for the solid and liquid states.
4. Sound arises when objects vibrate, irrespective of which object that is causing the sound.
5. The movement of a vibrating object is transmitted via particles in the air, i.e. ‘air particles’.
   Every movement from a single ‘air particle’ is transferred to the ‘air particle’ nearby in an interaction.
6. The movement of vibrating objects is transmitted in gaseous, liquid and solid substances via the particles in these substances. The movement of each particle is transmitted to the particle nearby in an interaction.
7. The closer the particles the faster the transfer of sound.
8. Sound transmission can be represented in different ways.
9. Sound transmission is an emergent process.
10. Sound transmission is a complex emergent process.

Hearing and auditory health

If the following content specific aspects are considered in teaching, the students’ opportunity to develop an understanding of hearing and tinnitus including how to maintain a good hearing health will be improved:

1. A number of concrete experiences of the hearing and its capability of registering different sounds.
2. It is emphasized that the ear consists of sensitive parts that are of crucial importance to our hearing. These sensitive components can be permanently damaged by loud noise in our everyday lives and we must take care of them.

3. The function of the ear is studied: vibrations in the eardrum are transferred via the ossicles to the internal ear where tiny, highly sensitive sensory cells (hair cells) transform the vibrations into electrical impulses which are transmitted to the brain where the impulses are interpreted. The own vulnerability and the risk of getting hearing impairment such as tinnitus including how to maintain a good hearing are emphasized in the teaching.

4. Content from several school subjects can with advantage be integrated into teaching about hearing and hearing health, and linked to students’ everyday life.

B. Aspects concerning the nature of science

Andersson and Wallin (2006) and Andersson and Bach (2005) have formulated a number of aspects concerning the nature of science that promotes learning school science with understanding. Thus, paying attention to the following aspects (1 - 4) would be beneficial (Andersson & Wallin, 2006, p. 682):

1. When the teaching content is a scientific theory, its character is made explicit (hypothetical in nature, can be used to explain and predict, can be tested by experiments and by observations, cannot be verified to the extent of being absolutely true, gives a consistent understanding of many phenomena and so on).

2. The differences between a scientific theory and faith are discussed. Their own way of understanding the world is respected.

3. The students are offered many opportunities to use the theory as an intellectual tool.

4. The teaching is planned and carried out so that the theory stands out as the main unifying thread.

There is a common use of models in science and in science teaching. These models are a simplified representation of an abstract phenomenon or a simplified picture of a concrete phenomenon. There are different types of scientific models such as biological, physical, chemical and mathematical models. If students learn to reflect on the models they encounter in school science, they are supposed to increase their opportunities to deal with models and the concept of models within science. For this reason, I would add a further dimension to the nature of science.

5. Students are given opportunities to reflect on the advantages and limitations of different models.

C. General aspects

Andersson and Wallin (2006) and Andersson and Bach (2005) have also formulated a number of general aspects that are applicable to many topics and school subjects, i.e. also valid outside school science. Thus, the following general aspects (1-7) are considered to promote learning with understanding (Andersson & Wallin, 2006, p. 684):

1. The teacher looks upon him-/herself as an active representative of the scientific culture, who introduces concepts, gives scientific explanations, and arranges situations for applications of these concepts and so on.
2. The teacher is well acquainted with common alternative ideas of the teaching content and is aware of these during teaching. He/she is attentive to and interested in the students’ ideas, both those already known through the literature and new ones.

3. The teacher creates a permissive classroom climate in which the students can share and discuss their ideas and reflections in a positive way.

4. A fair amount of time is used for discussing and solving problems/problems involving the students in having to apply the teaching content in different situations.

5. Deep learning is encouraged; that is, the pupil is stimulated to:
   - ‘twist and turn’ the new knowledge in his/her head (transformation instead of memorization),
   - ask questions and suggest ideas,
   - connect new knowledge with existing knowledge,
   - use knowledge as a tool for seeing the world around him/her with new eyes,
   - discuss what is new with classmates and others, and
   - accept challenges (e.g. in the form of set problems).

6. Formative evaluation is used in various ways by both teachers and pupils with the purpose of improving teaching and learning.

7. The teacher does not assume that the student is motivated but acts to create interest and motivation.

Students’ learning, interest and motivation are associated with each other, and there is a consensus that the teaching of school-science, particularly in physics and in chemistry, must necessarily evolve towards a more student-centered approach in which students gain knowledge and skills that are useful in their everyday life and of importance in their adult life (e.g. Aikenhead, 2006; Osborne & Dillon, 2008; Roberts, 2007; Schreiner & Sjöberg, 2007; Skolinspektionen, 2010; Skolverket, 2007, 2010). This includes also possibilities for students to practice argumentation and learn how to distinguish between scientific knowledge and opinions. Study III shows for example that some of the students’ explanations of why they consider themselves to stand loud music are built on myths (Arlinger et al., 2007; The National Board of Health and Welfare, 2003). Such examples are the ideas that it is possible to stand loud music if you are used to it or if you like it. In connection with argumentation exercises, students can be given opportunities to discuss the basis for such arguments. In accordance many researchers (e.g. Aikenhead, 2006; Osborne et al., 2004; Erduran & Jimenez-Aleixandre, 2007; Sadler, 2004) have emphasized that there is a need for young people to develop a critical approach to the current flow of information, and that their understanding of argumentation in general need to be developed including their competence in building arguments using scientific knowledge. Several of these studies show that there is a lack of these dimensions in science education. Therefore, I would like to add one more general aspect.

8. The teacher gives the students opportunities to take their stands in questions concerning everyday health and environmental issues including formulating arguments for and against their own standpoints. In this context the students are allowed to practice how to distinguish between values and science-based arguments.
The results in relation to the students’ age and gender

The results illuminate the capacity of 10-11 year old students to learn about sound, sound transmission, the function of the ear and hearing. In addition, the results suggest that their standpoints evolve in a health promoting direction on issues related to high sound levels and the use of ear plugs. The results also suggest that students’ understanding and learning of causal connections, their ability to develop general understandings and their reflections on the consequences of high sound levels, develop with age. Moreover, the older the students are the more they seem to realize that high sound levels can be harmful not only to others but also to themselves. These results confirm the pattern of young people being more critical to loud sounds as a result of age reported by other studies (Olsen Widén & Erlandsson, 2004b; The National Board of Health and Welfare, 2002). To conclude, teaching about sound, hearing and health increase young people’s knowledge and awareness of how to keep their hearing health.

There are no overall significant gender differences concerning students’ learning of sound, hearing and tinnitus. However, there are clear differences concerning students’ standpoints on issues related to high sound levels and use of ear plugs. The girls generally show more healthy standpoints and expressions than boys do. They also show greater awareness of their own vulnerability, and a higher proportion of the girls indicate that they have changed their behaviour into a more hearing healthy behaviour during the year after the teaching. These results correspond very well with other studies which also show that girls seem to show greater awareness in health issues relative to high sound levels (e.g. Kärrqvist & West, 2005; Olsen Widén & Erlandsson, 2004a; The National Board of Health and Welfare, 2002).

The teachers’ experiences

The main focus of the study was to investigate the students’ understandings of the content and their standpoints on the health issues in question. However, some results concerning the teachers’ experiences emanates also from the study. On several occasions, the teachers have found that the words and the concepts their students use clearly relates to the teacher’s own use of the school-science-social language (Amettlle et al., 2007; Mortimer & Scott, 2003). A well-defined and consistent use of terms and concepts seem to benefit student learning and thus their ability to express their understanding. These experiences underline the importance of students’ linguistic interaction with persons knowing more (Vygotsky, 1978).

Limitations of the present study

The outcomes form the field of education always is diverse and difficult to measure with accuracy (Hammersley, 2009). This study comprises of a complex study design and is relatively small scale based, and therefore any general conclusions cannot be drawn. Moreover, the scope of the study has not made it possible to collect corresponding data in any comparison classes, and for this reason you cannot say whether the design in this study work better or worse than other designs. However, if ‘the details are sufficient and appropriate for a teacher working in a similar situation to relate his decision making to that described’ (Bassey, 1981, p.85) then the results are useful for other designers as well as teachers. Another limitation is that no external evaluation has been accomplished, i.e. the third phase in the design experiment has not been implemented and investigated (Brown, 1992; Leach and Scott, 2008; Leach, Scott, Ametller, Hind & Lewis, 2006).
References


