10. SUMMARY

10.1 Introduction

In both national assessments (NU 2003) and international assessments (PISA, TIMSS) of compulsory school it has been shown that in recent decades students' results concerning science knowledge and science skills related to everyday life have decreased among Swedish students in grades 8 and 9 (e.g. Martin, Mullis, Foy, Olson, Erberber, Preuschoff et al., 2008; Skolverket, 2005, 2008, 2010). Swedish students in grade 4 participated for the first time in TIMSS 2007 (Bach & Frändberg, 2009). These students performed better in biology than in physics and chemistry, and students whose teachers felt well prepared to teach physics and chemistry had better results in these school subjects. Moreover, in the PISA study performed in 2009 among 15-year olds, the low-achieving students' results had declined more than others. Notwithstanding that results of assessments should be interpreted with some caution (e.g. Koretz, 2008; Serdar, Sørensen & Jakobsson, 2011; Sjøberg, 2007), the results do indicate a need for improved science teaching in Sweden.

Another element for consideration is students' interest in science and motivation for learning science. Bach and Frändberg (2009) reported from TIMSS 2007 that Swedish students' interest and confidence was high in grade 4. In contrast, Schreiner and Sjöberg (2007) reported from a large-scale international questionnaire, The Relevance of Science Education (ROSE), that Swedish students aged 14-16 considered other school subjects more interesting than science. One reason for this was that the students did not value science teaching as particularly interesting or inspiring, especially physics. Regarding students' interest in learning physics, their interest seems to decrease with age in Swedish compulsory schools (Skolinspektionen, 2010, 2011). Some reasons for this are that students think school physics is difficult, that teaching is monotonous and that there is no point in learning physics. Based on the above ROSE study, Jidesjö, Oscarsson, Karlsson and Strömdahl (2009) concluded that the Swedish compulsory school only meets the interests of a minority of students, namely those who choose to continue their studies in science and technology. They argued that school science must take into account what all students need to learn about in order to encourage the scientific literacy of all citizens.

The reports above indicate that school physics and chemistry linked to students' everyday lives and considering health issues would be interesting for both boys and girls and stimulate their learning. They also show that students should be given opportunities to practise critical thinking. This is in accordance with other studies showing that students, both girls and boys, are interested in learning science and technology related to humans and human activities, especially health and environmental issues (Baram-Tsabari & Yarden, 2005; Jenkins, 2006; Lindahl, 2003; Millar, 2006; Osborne, Simon, & Collins, 2003).

One health issue related to school science, which is becoming increasingly frequent, is the issue of loud sounds in young people's everyday life (EU, 2009). More young people than ever before have impaired hearing such as hearing loss and tinnitus (Chung, Des Roches, Meunier & Eavey, 2005). However, there are few health-related studies in the international science education literature (Harrison, 2005). Fensham (2001) also pointed to the lack of studies of students' learning of concepts related to environmental, technological and socio-scientific content, for example, noise pollution.

10.2 The overall aim and research questions

The aim of this thesis is to contribute to increased understanding of students' learning about sound, hearing and auditory health.

The research questions contribute to answering the overall aim by addressing the following issues:

1. What are students' understandings of sound and sound transmission before and after research-based teaching about sound, hearing and auditory health?
2. To what extent do students use a generalized theory about sound and sound transmission in their understanding before and after the teaching?
3. What are students' understandings of hearing and tinnitus before and after the teaching?
4. What are the students' standpoints on auditory health issues before and after the teaching?
5. How can a content-specific hypothesis be formulated that is valid for teaching about sound, hearing and auditory health?

The results are presented in three articles and as a summarized result in the form of a content-specific hypothesis.

10.3 Theoretical framework

The whole research project is based on a social constructivist perspective of *learning*. In connection with the design of the *teaching* materials, I have employed broader perspectives linked to social constructivism and these perspectives are also described. Since the project is a design-research study, visualising these perspectives is also important (Lijnse, 2010a). The ground for the analyses of the empirical material is presented in the three articles.

The social constructivist perspective

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 also 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. 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, 2009). Prain et al. place major emphasis on the importance of using representations in science learning.

Teaching and learning

Some more perspectives of students' learning linked to teaching and learning will be presented. One perspective is the influence of the *communicative approach* in the classroom (e.g. Lemke, 1998; Mortimer & Scott, 2003). Another important perspective in teaching is identifying the difference between students' alternative conceptions and the school scientific goals. This is done by the teacher by finding the epistemological difference, designated *learning demand,* between students' everyday social language and the school science social language (Ametller et al., 2007; Leach & Scott, 1995, 2002, 2008). Moreover the power of *formative assessment* is considered. Reviews of formative assessment point to the fact that formative assessment improves the students' motivation, self-confidence and learning (Black & Wiliam, 1998a, 1998b; Hattie, 2009; Hattie & Timperley, 2007; Shute, 2008). In doing this, there is also a need for clear goals of learning (Millar, Leach, Osborne & Ratcliffe, 2006). In addition, aspects of *scientific literacy* emphasize that literacy within science (vision I) and literacy about science-related situations (vision II) should be included in science teaching (Roberts, 2007). This also includes developing students' competence in constructing arguments on the basis of scientific knowledge (Osborne, Erduran & Simon, 2004). The different perspectives of teaching science that I have accounted for belong to the pedagogical content knowledge that is part of a *teacher's competence* (Zetterqvist, 2003).

10.4 Teaching design

The educational design used in this study is derived from traditions within educational design-based 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 to be 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 made 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 framework presented, a research-based teaching-learning sequence (TLS) 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, which teachers used as a resource for their own teaching. In this way, the TLS was tested, research results from practice were collected and evaluated and the teachers' guide was refined. This process was repeated several times. The results in this study are based on the research from the final cycle in which teachers made used of the guide presented in the appendix (West, 2008b).

10.5 Overview of the history of ideas

Since 500 B.C., philosophers, mathematicians and scientists have reflected over sound and sound transmission. The theory that sound requires a medium in order to be transmitted originated as early as in classical antiquity with Demokritos (400 B.C.), who imagined that the voice was air that had a certain form and was transported (Hunt, 1978). However, the Greeks did not have access to the modern concept of gas, and it is not so easy to know what they meant by air and how they conceived of its different processes. Aristotle (350 B.C.) suggested that air had to be compressed to enable sound to be transmitted, and that it was some kind of small air packet, a little wind, that moved forwards (Caleon & Subramaniam, 2007). The Roman Lucretius (75 B.C.) believed that when a person screams loudly, "atoms of voice's" pass the narrow gullet in such large amounts that they cause pain (Eshach & Schwartz, 2006). Lucretius also had the idea that sound passes doors by way of invisible fissures. At the beginning of the 1600s, there were still some scientists who believed that sound involves a transfer of matter from one place to another. For example, Gassendi imagined that sound transmission meant that a flow of atoms was emitted from a sound source (Blood, 2009). A similar idea was expressed by Beeckman, who thought that each vibrating object splits up the surrounding air into small, round, air-filled bodies, which are sent off in all directions and which are perceived as sound when they reach the ear (Caleon & Subramaniam, 2007). Evidence that sound transmission had to do with matter, without necessarily being the same as a net transfer of matter, was put forward by Boyle and Hooke (1600s). According to Hunt (1978), Boyle ultimately proved that sound cannot travel in a vacuum. At the beginning of the 1700s, scientists reached an agreement that sound could only be transmitted through a medium. To summarise, the idea that sound propagates as invisible particles or as delimited substances, that is, a net transmission of matter, has thus existed for a long time.

10.6 Methods and data

The approach was to explore the students' conceptions and learning about sound, hearing and auditory health including the students' standpoints as regards loud sounds when teachers implemented the TLS in practice. Seven teachers from four Swedish schools and their 199 students from grades 4 (aged 10-11), 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 them and wrote extensive field notes. The data from the teachers' diaries, students' notebooks and notes from my visits were used as sources to obtain 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 teaching by formulating goals for students' learning using ideas in the Teachers' Guide (West, 2008b). These goals guided the content of the lessons, but depending on the individual teacher and their students, they were treated more or less in depth. The total time used for the teaching about sound, hearing and auditory health was around 15-20 hours.

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

10.7 Summary of the studies

Article 1

West, E. (2011). Learning for Everyday Life: Pupils' conceptions of hearing and knowledge about tinnitus from a teaching-learning sequence. *International Journal of Science Education*, 33(9), 1245-1271.

The first article answers the third research question, which explores 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 the students in grade 4, and half the students in grade 7 and 8 listen to music daily or almost daily 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 the students in grades 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 involved 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 retention of this knowledge was good even one year after the intervention. 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, it is beneficial to teach about hearing and tinnitus as early as 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.

Article 2

West, E., & Wallin, A. (2011). Students' Learning of a Generalized Theory of Sound Transmission from a Teaching-Learning Sequence about Sound, Hearing and Health. *International Journal of Science Education*.
doi: 10.1080/09500693.2011.589479

This article answers the research questions 1 and 2, which explore students' learning of sound and sound transmission. Learning abstract concepts such as sound often involves an ontological shift since conceptualizing sound transmission as a process of motion requires abandoning sound transmission as a transfer of matter (Carey, 1991; Chi, Slotta & De Leeuw, 1994; Reiner, Slotta, Chi & Resnick, 2000). Thus, the ability of students to grasp and use a generalized model of sound transmission, that is using the same theory for sound transmission in different media, 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' understanding 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 indicate some crucial points in teaching and learning about the scientific content of sound. No systematic gender differences were found in the results.

Article 3

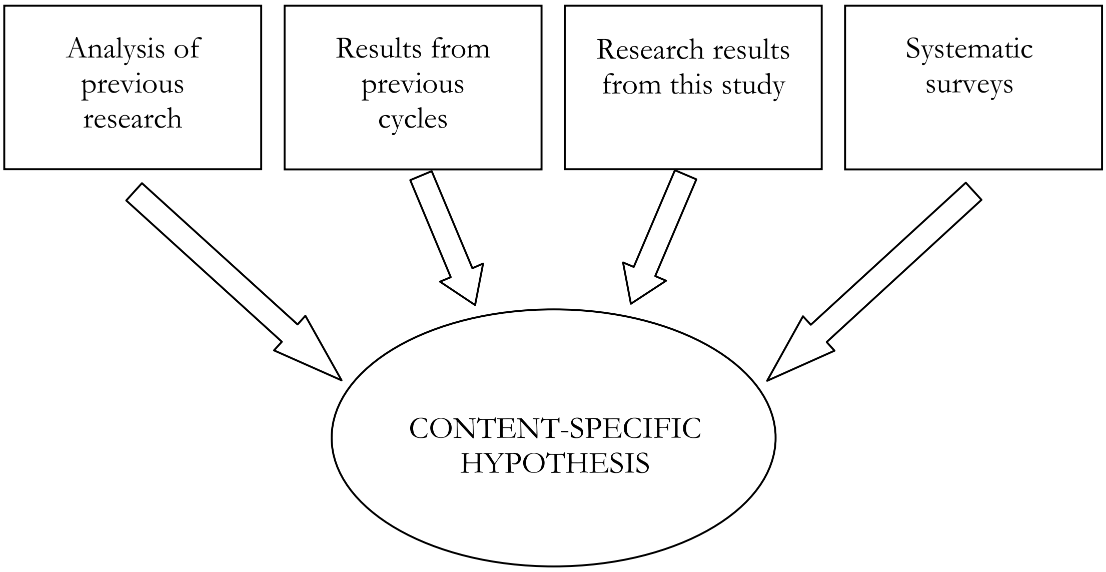
West, E. (submitted, 2011). Learning for Everyday life: Students' standpoints on auditory health issues before and after a teaching-learning intervention.

This article answers research question 4, which investigates the students' standpoints on auditory health issues before and after the teaching. Researchers have highlighted the growing problem of loud sounds among young people in leisure-time environments, recently even emphasizing that portable music players carry the risk of leading to hearing impairments such as tinnitus. However, there is a lack of studies investigating compulsory school students' standpoints and explanations in connection with teaching interventions integrating the content of school subjects 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 involving loud sounds after the intervention and especially among the older ones this result remains or is 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 knowledge of sound, hearing and auditory health, then it emphasizes the importance of integrating health issues into regular school science.

10.8 Content-specific hypothesis

This chapter answers the final research question that aims to formulate a content-specific hypothesis that is valid for teaching about sound, hearing and auditory health.

The content-specific hypothesis is composed of a combination of my research results, previous research results, results from the iterative research cycles preceding the final cycle and systematic national and international surveys (Figure 10.1).



Figur 10.1 Construction of a content-specific hypothesis for teaching about sound, hearing and auditory health.

Content-specific hypothesis

The combined results from the studies are summarized into a content-specific hypothesis for teaching. It is formulated by a combination of aspects concerning 1) sound and sound transmission, 2) hearing and auditory health, and finally 3) common aspects of the whole area of sound, hearing and auditory health. The hypothesis can be tested in new design experiments, and if it withstands future tests, it can be developed into a content-specific theory for teaching about sound, hearing and auditory health.

If the following content-specific aspects are considered in teaching, the students' opportunities to learn and understand the theory of sound and sound transmission, hearing and auditory health will be improved:

Sound and sound transmission

1. Sound arises when objects vibrate, irrespective of which object is causing the sound.

2. The movement of a vibrating object in air 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.
3. 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.
4. The closer the particles, the faster the transfer of sound.
5. Different ways of representing sound transmission need to be problematized in teaching.
6. Sound transmission is an emergent process.
7. Sound transmission is a complex, emergent process.

The meanings of the emergent processes need to be explained. Sound transmission as an emergent process means that the transmission is a large-scale process whose motion differs from the motion of the constituent particles. Additionally, the complex process also includes that the transmission is influenced by elastic and inertial properties.

Since it is difficult for students to understand sound transmission, and especially to grasp a generalized theory of sound transmission through all media, their learning faces major challenges. According to Chi (2005), a characteristic of such challenges is that they are held across historical periods, and this was confirmed by historical overviews of ideas about sound and sound transmission.

Hearing and auditory health

1. A number of concrete experiences of hearing and its capacity to register 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 that are transmitted to the brain where they are interpreted. The students' own vulnerability and the risk of suffering from hearing impairment such as tinnitus, as well as how to maintain good hearing, are emphasized in the teaching.

1. Content from several school subjects can be integrated into teaching about hearing and auditory health, and linked to students' everyday life.

10.9 Conclusion, discussion and implications

The results are discussed in relation to the students' age and gender and the teachers' experiences are summarized and discussed. Moreover, there is a general discussion of the results from this thesis, including the limitations of this study. The chapter ends with some ideas for further research and a final reflection.

The results in relation to the students' age and gender

The results show that it is beneficial to teach 10-11 year old students about sound, sound transmission, the function of the ear and hearing and auditory health. They can learn that sound transmission is a process of motion and not a transfer of matter. 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 hearing-protection devices. The results also suggest that students' understanding and learning of causal connections, their ability to develop a general understanding 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 they grow older reported by other studies (Olsen Widén & Erlandsson, 2004b; Socialstyrelsen, 2002).

There are no overall significant gender differences concerning students' learning about sound, hearing and tinnitus. However, there are clear differences concerning students' standpoints on issues related to high sound levels and use of hearing-protection devices. 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 more auditory healthy behaviour during the year after the teaching. These results correspond with other studies, which also show that girls seem to show greater awareness in health issues related to high sound levels (e.g. Kärrqvist & West, 2005; Olsen Widén & Erlandsson, 2004a; Socialstyrelsen, 2002).

Formative assessment

Formative assessment has been used as a connecting idea which the teachers continually used throughout their teaching. The impact of formative assessment on student learning is discussed in Articles 1 and 2. The results suggest that formative assessment and the quality of feedback have had an impact on students' learning. Moreover, formative assessment has had an impact on teachers' learning. All the teachers stated in their diaries and in interviews that the formative assessment changed their view of students' learning and their own teaching. This is also what Black, Harrison, Lee, Marshall and Wiliam (2003, 2004) and Nyberg (2008) describes from their interactions with teachers in various educational projects. In addition, teachers have stated that more students achieve the goals when their teaching is based on formative assessment. In the light of this result, it is interesting to note the Swedish trend showing that low-achieving students' results had declined more than others in PISA 2009 (Skolverket, 2010). Therefore, formative assessment might contribute to turn this trend.

As an example of the impact of formative assessment, one teacher wrote the following in her diary:

> One of my students said today that it's just as well to ask from the beginning because you check anyway if I have understood. (West, 2008b, p. 115)

The results from this study are consistent with the reviews of research that show that formative assessment and relevant feedback to students is a powerful tool for improved learning (Black & Wiliam, 1998a, 1998b; Hattie & Timperley, 2007; Shute, 2008).

Experiences of language in the classroom

The main focus of the study was to investigate the students' understanding of the content and their standpoints on the health issues in question. However, some results concerning the teachers' experiences also emanate from the study. On several occasions, the teachers found that the words and the concepts their students used clearly related to the teacher's own use of the school science social language (Amettler et al., 2007). A well-defined and consistent use of terms and concepts seems to benefit student learning and thus their ability to express their understanding.

General discussion of the results and implications

Article 2 clarifies that teaching an abstract area like sound and sound transmission offers challenges for both teachers and students. Article 1 also shows that it can be difficult for adolescents to understand the meaning of the risk associated with loud sounds, and that knowledge of hearing and tinnitus may be an important prerequisite for conceptualizing the risk of being exposed to loud sounds. Moreover, article 3 indicates that students' auditory health awareness, especially among the girls, has increased after teaching, and there are also signs of behavioural change in relation to loud sounds.

The content-specific hypothesis developed in this thesis provides a basis for further research and contributes to improving practice. This might be important especially as fewer Swedish students have been given opportunities to learn about sound than students in many other countries (Martin et al., 2008). Additionally, many researchers ask for health education in schools as an important part of the work on maintaining good auditory health (e.g. Berg & Serpanos, 2011; Berglund, Lindvall, Schwela & Goh, 1999; Bulbul, Bayar Muluk, Çakir & Tufan, 2009; Daniel, 2007). The new Swedish curriculum, Lgr 11, offers possibilities for using the content-specific aspects in teaching since there are explicit goals concerning sound and auditory health in several school subjects (Skolverket, 2011). However, teachers with a high degree of pedagogical content knowledge are also important for putting this into practice, and they are equally important in grades 4-6 as in grades 7-9 (e.g. Bach & Frändberg, 2009; Linder & Erickson, 1989; Zetterqvist, 2003), especially since these younger students seem to be more interested in learning science than the older students (Lindahl, 2003; Martin et al. 2008; Osborne & Dillon, 2008).

The strengths and limitations of the present study

The contributions from educational design research are 1) theoretical contributions by developing content-specific didactic knowledge, 2) pragmatic contributions to teaching practice by bridging the gap between theory and practice, and finally 3) professional development of participants involved in the research (McKenney, Nieveen & Van den Akker, 2006). There are limitations related to design-research such as "design-based researchers are not simply observing interactions but are actually 'causing' the very same interactions they are making claims about" (Barab & Squire, 2004, p. 9). Outcomes from the field of education are always diverse and difficult to measure with accuracy (Hammersley, 2009). This study has a complex design and is relatively small scale, and therefore general conclusions cannot be drawn. However, since design research is context-bound, it does not strive for context-free generalizations (van den Akker, Gravemeijer, McKenney & Nieveen, 2006). Nevertheless, "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.

Specific considerations as regards method, including limitations associated with the articles, are discussed in the respective articles. Examples are the validity of the tests, inter-rater reliability considerations and the impact of the method response factor.

Ideas for research and final reflection

This thesis has generated several new research questions such as:

> How can teaching about sound and sound transmission and thus the content-specific hypothesis for teaching be further improved so that students' learning of a general theory for sound transmission is additionally stimulated?

My study shows that students have increased scientific knowledge about sound and hearing after the teaching, and that much of this remains the following year. Students' awareness of their own auditory health has also increased after teaching. Besides, there are signs that this awareness has increased during the following year. A final conclusion of the results from this thesis is what Feinstein (2011) asks for:

> […] science education can help people solve personally meaningful problems in their lives, directly affect their material and social circumstances, shape their behavior, and inform their most significant practical and political decisions. (p. 169)

Therefore, the results of this thesis can be seen as indicating that appropriate science education can enhance students' competence to prevent health-related personal problems that have social consequences - here problems with hearing and consequences such as tinnitus.