

SOUND AND SENSIBILITY. PRE-SERVICE SCIENCE TEACHERS BRIDGING PHENOMENA AND CONCEPTS

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ABSTRACT. This paper reports from a 2 year empirical study of pre-service science teachers exploring the phenomenon of sound. The research design is based on the phenomenological approach to science education, starting from careful descriptions of phenomena as experienced before introducing scientific concepts. The purpose of our study is to explore how science teachers conceive the relation between a phenomenon as *experienced* and *described* and the scientific concepts *explaining* it. How do they experience a particular sound phenomenon, and how do they link these experiences with scientific concepts when planning a lesson? Data were generated by involving them in listening and describing a sound, then planning and presenting a lesson which linked these descriptions to scientific concepts on sound. The results show that the science end of the bridges established by pre-service science teachers was wider in the sense of being quantitatively more prevalent in their planned lessons than that end of the bridge which rested in sense perceptual lifeworld experience. The majority of participants presented lesson plans based on an *illustrative-deductive* approach. A minority based their plans on a *genetic-inductive* approach; starting from experience and proceeding to scientific concepts. This was in spite of the fact that non-scientific, more or less imaginative associations were more prevalent in the rich picture of the described sound phenomenon. This conclusion points to the need for science teachers to develop courage to use their own and their students' immediate perceptual experiences as "raw material" for building that end of the bridge which rests in the perceptual lifeworld of our common human experience.

Introduction

In the phenomenological approach to science education, the starting point is the careful description of lifeworld phenomena. In his phenomenological approach to science education, the German science educator in physics and mathematics Martin Wagenschein claims that the main problem in science teaching is that it is too often planned "from the end": Starting with the basic concepts and the mathematical structures, phenomena themselves are hardly touched upon as the teacher hurries on into the world of abstract concepts, "so that the children no longer can participate with their eyes, ears and hands" (Wagenschein, 1983, pp. 108-109; our transl.). In contrast, a science teaching planned "from the start" presumably must involve a primary focus on perceptual lifeworld experience and a secondary cognitive or reflective activity in which these experiences are understood or explained. In this paper we refer to this as the genetic-inductive approach to learning contrary to the illustrative-deductive approach, starting with the concepts and subsequently seeking illustrations for understanding the concepts.

Students often experience a gap between everyday life and school science. Bouillion and Gomez (2001), for example, report a disconnection between schools and students' home communities. They suggest a "connected science" in which real-world problems and school-community partnerships are used as scaffolds for bridging students' everyday experience and school-based knowledge. Further, Lyons' (2006) review of research from different countries suggests that students' experiences of school science are much the same all over the world: it is "difficult" as well as "unengaging" and personally irrelevant. The phenomenological approach to science education takes all experience as real, at least in a primary or primitive sense of the term (Spiegelberg, 1994).

Phenomenology has a wide range of definitions and applications. As a branch of philosophy it may be described as a philosophy of knowledge (epistemology) and being (ontology) in which 1) all possible human experience is considered equally significant for our understanding of the world; and 2) the subject – object relation is of an internal nature, i.e., subject and object must be seen as belonging together, as two aspects of one (non-dualistic) whole. The essence of phenomenology is "to return to *concrete*, lived human experience in all its richness" (Moran, 2000, p. 5; italics in original). It never neglects sense experience or puts it aside as merely subjective, but uses it as a starting point for systematic investigation, reflection and understanding. The intention is to follow Edmund Husserl's dictum "to go back to the 'things themselves'" (Husserl, 1970, p. 168).

The development of a "Phenomenon-based Science Education" has since 1999 been an ongoing activity in the science teacher education program at the Norwegian University of Life Sciences where the first author of this paper is teaching. This activity is based on the notion of phenomenology as an attempt to understand phenomena from *within*, by describing them "in the broadest sense as what ever appears in the manner in which it appears, that is as it manifests itself to consciousness, to the experiencer" (Moran, 2000, p. 4). To apply phenomenology to science education entails an interplay between building a theoretical foundation for a phenomenological science education and developing pedagogical teaching guidelines for science teachers and science teacher educators (Østergaard et al., 2008). The program is practice based, emphasizing training of basic competencies and skills for becoming a teacher.

Purpose and Research Questions

Our paper is based on interview and observation data from the science teacher program referred to above. The aim of the paper is to explore how pre-service science teachers conceive of the relation between a particular lifeworld phenomenon and the scientific concepts or models connected to this phenomenon. For this study we chose the phenomenon of sound. The following research questions are addressed: How do pre-service science teachers develop a rich picture of a particular sound phenomenon using their sense experiences as points of departure? How do they link these perceptual experiences with scientific concepts connected to sound? What, if any, intermediate notions do they think useful in teaching the scientific concepts of sounds?

Methods

The empirical data in this study is generated by involving pre-service science teachers in a three step exercise: In the *first step* they were asked to close their eyes and just listen to the sound phenomenon produced by rubbing the finger on the rim of a crystal glass. This is a classical phenomenon,

explored amongst others by Michael Faraday (Faraday, 1932) and Galileo Galilei in his experiments on musical acoustics (Settle, 1996). The glass was rubbed at least for half a minute, and this was repeated three times with variations of rubbing speed and intensity and with a second glass rubbed simultaneously by another person. After every repetition, the teachers wrote down, in silence, their answers to the task given: “You will now hear three sounds. Try to describe what you hear, with your own words.” In the *second step*, the teachers worked in groups of four, choosing between these words and expressions in order to build a “bridge” between the expressions and one of the following three scientific concepts connected to sound: frequency, decibel and noise. In this phase of the exercise we did not collect empirical data, as it served as a preparation for the plenary presentation in the *third step*. Here, each group presented the results in class, emphasizing their reflections on how they chose words or expressions from the initial manifold of descriptions, how they linked to these descriptions of perceptual experiences with the chosen scientific concept, and whether they had to establish new, intermediate notions in order to reach the scientific concepts end of the bridge.

Two classes of pre-service science teachers from 2007 and 2008 (with a total number of 36 students) took part in these exercises. The students had been introduced to phenomenological observation methods, but they had not exercised these methods extensively. The words and expressions from the first part of the exercise were gathered from both classes and subjected to a content analysis. This resulted in ten categories describing different domains of experience associated with the sounding glasses. Both authors worked together on this analysis, eventually establishing an inter-subjective agreement.

In addition, students in the 2008 class (19 students) were video-recorded while performing the third step of the exercise, that is, when they presented the results of their group work in plenary. The video-recorded presentations were subjected to a “meaning concentration” (Kvale, 1996) focusing on how the bridge between sense perceptual experiences and the scientific concept(s) was build. Here, also both authors worked together towards inter-subjective agreement.

Results and Discussion

We have chosen to present the results and the discussion of the results stepwise: We start with the pre-service teachers’ answers to the task given: “You will now hear three sounds. Try to describe what you hear, with your own words” (first step). We will then move on to the presentations of the 6 groups attempting to link perceptual experiences with the chosen scientific concept (third step).

Categories of Expressions of Sense Perceptual Experience

The participating pre-service science teachers created a rich perceptual picture of the phenomenon “crystal glass/es being rubbed with a finger”. A rich picture in this sense implies using multiple ways of describing and intuitively naming the perceived phenomenon. Terms from everyday language were used, as well as imaginative associations and scientific concepts. Some of these terms were both scientific and everyday in character, for instance “noise”, which created some ambiguity for the analysis. All in all, a total of 243 expressions¹ were registered. In table 1 examples of the words in each category are given. We distinguish between the total number of expressions in each category (f_1) and the number of qualitative different expressions in each category (f_2).

¹ Two expressions did not fit into either of the categories: “different levels of sound” and “tones (different)”. With these, the total number of expressions was 243.

Table 1. Categories resulting from an analysis of words and expressions associated with “crystal glass/es being rubbed with a finger”. f_1 = number of expressions in each category/group, f_2 = number of qualitative different expressions in each category/group.

Category	Examples of words, expressions or concepts	f_1	f_2
A1: Synaesthetic metaphors / sound descriptions	Light tone/sharp sound, ice, cold, cold sound, dry sound, “rusty” sound, beautiful sound, light, pervious sound, monotone sound, whining sound, shafts of sunlight through the trees in the wood, floating, icicle, sun, blue, big room.	39	28
A2: Wave/rhythm-images	Vibration, rhythm, repeating, rhythmical pattern, periodical, shrilling vibrato, swinging, circles, pulsation, beat.	21	14
A3: Tone description	High intense tone, high shrilling tone, penetrating tone, deep shrilling tone, uneven tone, recognizable tone.	13	6
	<i>Total number of expressions in this group:</i>	73	48
B1: Sounds of nature	Ocean, bee, conch, sounds of the wind, as waves.	6	5
B2: Sound of music and music instruments	Music, melody, very melodic, church music, music instrument, church bell, church organ, accordion/organ (not properly played), fiddle, fiddle out of tune, electronic instrument, wind instrument, didgeridoo, glockenspiel, Jazz music, choir, song with varying tones, scream, falsetto.	41	29
B3: Sounds of other man-made objects	Alarm, alarm clock, war alarm, siren, saw mill, machines, foghorn, noise, slamming door, train whistle, brakes, trash being pressed together, test picture on television, traffic accident, dentist.	41	19
	<i>Total number of expressions in this group:</i>	88	53
C1: Feelings & bodily sensations	Melancholy, intense, harmony, disharmony, lamenting, uncomfortable sound, irritating, sterile, discomfoting, not discomfoting, a bit spooky getting headache, pain in the ear, irritating, unease, deafening, delight.	38	21
C2: Mythical/fairy tale associations	Troll-chthonian, Huldra [name of Nordic female fairy tale being, living in the woods], “trolley” sound.	3	3
C3: Abstract expressions	Emptiness, outer space, interplay, silence, war, connected sound image, exotic, heaven, electricity.	14	12
	<i>Total number of expressions in this group:</i>	55	36
D: Scientific terms	Glass friction, overtone, interference, resonance, high frequency, volume, harmonious frequency, fluctuating high frequency, interference, resonance, wave length, sinus wave, sound waves, amplitude.	25	18
	Total number of expressions:	241	155

The analysis resulted in ten categories in four groups:

A. Four categories contain expressions and words attempting to describe and characterize the *sound itself* and/or the quality of the sound:

1. *Synaesthetic metaphors* are expressions which relate to *synesthesia*, involving more than one sense. In this case, hearing of a sound produces for example visual images or colors. In descriptions of one kind of sense impression words are used that normally describe another.
2. *Wave/rhythm-images* are expressions which intend to describe the phenomenon as waves, circles and rhythmical patterns.
3. *Tone descriptions* are expressions which in different manners characterize the sound as a (musical) tone.

B. Three categories contain expressions and words which are associations to other *sound sources* than the crystal glass being rubbed. These expressions refer to the sound producing objects, sources which might produce a similar sound:

1. *Sounds of nature* are expressions describing sound sources in nature.
2. *Sound of music and music instruments* are expressions explicitly referring to music, musical sounds and musical instruments.
3. *Sounds of other man-made objects* are expressions containing sounds produced by mechanical machines and instruments having an alarm character, as for example foghorn.

C. Three categories contain expressions and words emerging out of *associations and feelings* which listening to the sound awake. These expressions do not explicitly refer to a sounding object.

1. *Feelings & bodily sensations* are expressions referring to moods and emotional conditions.
2. *Mythical/fairy tale associations* are expressions referring to figures from fairy tales.
3. *Abstract expressions* are expressions which neither are describing concrete sounds, sound experiences nor mental associations.

D. *Scientific terms* form a category on its own because these concepts, having a (more or less) scientific definition, are the concepts which the teachers should build a bridge towards.

As can be seen in the table, the teachers created a rich picture as a response to the task of describing the sound phenomenon. Of a total of 241 expressions and words specified, 155 of these were qualitative different words/expressions. Only a limited number of expressions were repeated with exactly the same words. Amongst these we find “alarm” (8 times), “music” (7), “light tone/sharp sound” (6), “irritating” (6), “discomforting” (6), “high intense tone” (5), “vibration” (4), “repeating” (4), “high frequency” (4), and “siren” (4). Most of the expressions (118 out of 155) were mentioned only once.

Discussion: Expressions of Sense Perceptual Experience

The largest category group is B (sounds of nature, music and musical instruments and other man-made objects) with 88 expressions of totally 241 (nearly 37%). The high percentage may be due to the way the exercise was formulated: “You will now hear three sounds...”, stating the phenomenon as a sound phenomenon. While the teachers responded to the task of describing the sound, they did this, however, in terms of “this sounds *like...*”, for example the ocean, music or an alarm. The descriptions in this group are thus more of associations to the sound than descriptions of the sound itself.

Attempts to describe the sound itself we find in the second largest category group A with 73 expressions (30% of total). Category A1, “Synaesthetic metaphors / sound descriptions”, contains descriptions of the sound, as “pervious sound”, and synaesthetic descriptions of the sound, as “dry sound” and “cold sound”. Attempting to describe the phenomenon, a phenomenon clearly connected to the sense of hearing, the science teachers made use of other senses, as the tactile (“dry”) or visual (“blue”) senses. Such synaesthetic paraphrasing is commonly used when describing sound qualities in a musical setting. In his classical textbook on orchestration Rimsky-Korsakov (1964) notes that it is “a difficult matter to define tone quality in words; we must encroach upon the domain of sight, feeling, and even taste” (p. 18). Another music related category A3 “Tone description” is, although

containing rather few expressions (13, a little more than 5%) defined as a separate category. The notion of a (musical) tone was not introduced in the exercise; it clearly emerged out of the science teachers' attempt to characterize the sounding phenomenon. Galileo also referred to the sounds of a goblet being rubbed with a finger as "musical tones" (Settle, 1996, p. 23).

Words and associations connected with music and music instruments in category B2 (17%), together with category A3 "Tone description" (5%), represent 22% of total number of answers, making music-related expressions the most frequently occurring answers. This might indicate that musical expressions and music-related words are relevant for perceiving sound in everyday life. When (intentionally) experiencing sound music seems to be a well-known lifeworld phenomenon. It is, however, quite another question as to how this can be used to connect to scientific concepts.

Two other categories have about the same size as category B2: Category B3 "Sounds of other man-made objects" (17%) and category C1 "Feelings and bodily sensations" (16%). Words in these categories represent associations to sounds produced by well-known everyday sound sources ("train whistle", "brakes", "alarm clock" etc.) and the imprints these sound make emotionally ("intense", "harmony", "sterile" etc.). Here, again, the science teachers did not respond directly to the task of describing the sounding phenomenon; they rather seemed to be responding to "what does this *sound like?*" and "what does this sound *make you feel?*" It is also interesting to note that, when referring to other sound sources, less than 3% refer to sounds in nature, whereas 34% of the responses are connected to sounds of man-made objects (B2 and B3). This may be due to the fact that a crystal glass being rubbed produces a sound of a man-made object, thus associating with similar sounds of other man-made objects.

In contrast, the more or less scientific associations in category D make up only about 10% of the responses. Most of these concepts were pronounced in a scientific way (without giving a scientific *explanation* of the concept), as for instance "interference" and "resonance". There were also, however, examples of concepts with a semi-descriptive character, as for instance "high frequency". This might indicate that the pre-service science teachers attempted to incorporate science knowledge into their perceptual descriptions of the sounding phenomenon. On the other hand, the relatively low percentage in this category may very well be due to the task of the exercise with its genetic-inductive character, moving from the particular to the general, from the experiential-based end to the science-based end of the bridge.

From a science learning point of view it is interesting to note that these responses reveal the skills of *describing*, *experiencing* and *explaining* the perceived phenomenon, although they actually all are answers to the question "*describe* what you hear, with your own words". A minor part of the responses can be regarded as actual descriptions of the phenomenon, in terms of giving a precise characteristic of *what is heard*. Many of the responses are such that they attempt to describe the phenomenon by connecting to how the teachers experienced the sound impression. For instance, words in categories B2 and B3, referring to musical sounds or to sounds made by other man-made objects, do not explicitly describe the sound itself (what is the connection between the sound perceived and church music?). The group of the sound as experienced is the largest of the three, encompassing such different terms as "icicle" (A1), "didgeridoo" (B2) and "irritating" (C1). The attempts to explain the sounding phenomenon, as "vibration" and "pulsation" (A2) or "overtone" and "interference" (D) are few, again probably due to the exercise's genetic-inductive character.

Did the students use these experiences in their group exercises, constructing a bridge from perceptions to concepts? In the next section we will present and analyze the group presentations.

Linking Perceptual Experiences with Scientific Concepts

The next step of the exercise for the pre-service science teachers was to choose among the words and expressions as starting points for moving towards the scientific understanding of the phenomenon. Here, they had to identify and name different steps or stages of the bridge between the experienced phenomenon and the cognitional scientific concept. There were 6 presentations in the 2008 student group. In table 2 the central aspects of each one of these presentations are summarized.

The analysis of these presentations resulted in two different approaches to learning and teaching:

A. *The illustrative-deductive approach* is characterized by first introducing the concept, then finding illustrations for understanding the concepts. A deductive approach to teaching essentially starts by giving the learners rules or concepts which the learners when use when exploring a phenomenon.

B. *The genetic-inductive approach* is characterized by starting from what is sensed and experienced before narrowing down to scientific concepts. The *genetic* aspect emphasizes that the learners should be given the opportunity to use their personal knowledge and experience as a starting point for creative thinking and conceptual understanding (Wagenschein, 1968). An inductive approach essentially starts by letting the learners explore phenomena themselves. From these explorations they might experience how (general) rules and concepts are expressed in (specific) phenomena.

As is shown in table 2 not all of the groups were capable of employing the genetic-inductive approach, the learning approach in their exercise of linking the experiences to scientific concepts. In group 3, however, one of the teachers explicitly connected perceptual experiences and the concepts of amplitude and decibel (figure 1). The teacher explained that when the rim of the crystal glass is rubbed harder, the waves on the water in the glass increase and that there is a perceptual link between how hard the glass is rubbed and the (observed) height of the waves, leading on to the concept of amplitude and decibel. The teacher introduced the concepts of pressure and energy – concepts not among the 241 expressed in the rich picture – in order to connect the perceptual and the conceptual ends of the bridge.

Phenomenon -> pressure on the glass -> energy -> height of waves> amplitude -> decibel

Figure 1: A bridge between the sounding crystal glass and the concepts of amplitude and decibel

Another particularly clear example of such a bridge is from one of the groups in the 2007 class. Here, also the pre-service teachers' reasoning visualized the use of sense experiences in order to move toward the concept of frequency (figure 2). By using the expression of "something which goes round and round", and by joining this to the perceptual notion of vibrations, the other side of the bridge (concepts of wave speed and frequency) is reached.

Phenomenon -> "something which goes round and round"/"swinging" -> vibrations -> waves -> wave speed -> frequency

Figure 2: A bridge between the sounding crystal glass and the concept of frequency

Table 2. Categories resulting from a qualitative analysis of 19 pre-service science teachers (in 6 groups) presenting bridges between perceptual sound experiences and scientific concepts.

Groups	Description of group presentations	Category
1. group: 4 students (dur. 3.55 minutes)	Students could investigate sounds in bottles, make observations and draw conclusions which the teacher could write on the blackboard. After that the teacher could introduce theoretical concepts. By blowing in bottles the air is put to movement; it has to go down to the bottom and then back up to the top so the length of this swinging up and down depends on the height of the bottle; the longer the bottle, the longer the way and the deeper the sound; a shorter bottle means shorter way up and down which means higher sound; hence the frequency concept. The teacher could tell the students this.	<i>Illustrative-deductive approach</i>
2. group: 3 students (dur. 3:42 minutes)	Students could use glasses and bottles. The teacher could give them the task to rank them according to pitch because that is a concept they already know. Then they will find that a empty glass has the highest pitch, second the glass bottle and third the plastic bottle. [Teacher draws on blackboard the glass and the two bottles above each other and beside each an ear.] Because what we hear is connected with frequency, the higher the pitch the higher the frequency. Between bottle and ear there are waves. The frequency of the waves decides how high or low the sound is. [Between the glass and the bottles and the ear the teacher draws wavy lines illustrating different wavelengths.]	<i>Illustrative-deductive approach</i>
3. group: 3 students (dur. 6.58 minutes)	1: We tried to start from sensing and hearing [demonstrates how the pitch sinks when more water is poured into the glass] the same amount of energy goes in [by keeping the pressure and the speed of the moving finger constant]. There was more and more inertia in the sound, it became slower the more water there was in the glass – when we hear that the tone gets lower and lower it is exactly as if it goes slower and slower – so the number of waves [per second] gets less, the students can hear number of oscillations per time unit, and this leads us to the concept of frequency. 2: Decibel has something to do with energy: When you press harder on the glass we can see that the waves on the water increase and we heard that the sound also gets more powerful. The effect of energy [of the moving finger] corresponds to the height of the wave tops, this leads to the concepts of amplitude, decibel, and oscillations. 3: First the students must get a feeling for the concepts and what frequency and decibel is about in order not to be confused. The students should first understand what frequency as a concept is, after that they can explore the phenomena themselves.	<i>Genetic-inductive approach/ Illustrative-deductive approach</i>
4. group: 3 students (dur. 3.32 minutes)	1: We thought about explaining what decibel is by letting the students blow with different intensities into the bottles, producing high sounds and low sounds. 2: We were quite confused when we tried with different amounts of water in glass and bottle, that the effect is the opposite. We could not understand the opposite change in pitch in bottle and glass [as a result of more water added]. 3: We also tried to understand what noise is. We produced it on the rim of the glass, it something vibrating something discomfoting.	<i>No clear approach (Illustrative-deductive approach)</i>
5. group: 3 students (dur. 2.30 minutes)	1: We want to use not only the sense of hearing, but also other senses like sight and touch. One can feel that the glass vibrates, this leads to frequency and sound. 2: We talked about how sound is perceived in the ear. In your class [pointing at the other teacher], you asked, what sound is, and they answered, it just comes to you. When the finger moves on the glass one can hear it like a wave, perhaps one could go on from that experience?	<i>No clear approach (Genetic-inductive approach)</i>
6. group: 3 students (dur. 1.54 minutes)	1: We start with associations, what sound is, we agreed on that noise is undesired sound. But very soon we had the need to find out what sound really is, so we looked in the articles [a collection of facts on sound concepts, handed out at the beginning of class – only to be used in emergency]. So, we forgot the inductive approach, it just disappeared. 2: If I would have a class, I would start with a dog's whistle, possibly also with a dog. This might make the students curious; why don't I hear anything, why does the dog hear the whistle?	<i>No clear approach (Illustrative-deductive approach)</i>

Both bridges represent but two of multiple possibilities for connecting what is heard and experienced with concepts from science curriculum – concepts which these pre-service science teachers one day most likely will introduce in their own class.

Discussion: Links between Perceptual Experiences and Scientific Concepts

The group presentations clearly show that pre-service science teachers feel more at home in the illustrative-deductive approach than in the generic-inductive approach, despite the fact that the exercise clearly encourage to use the latter approach. As in the case of group 1, the teachers seemed to take the illustrative-deductive approach, although they first allowed the students to make their own unsystematic observations. They suggested that the teacher should step in and explain the concepts, either by taking up examples from the students' observations or finding their own illustrations. The same approach is basically also found in group 2, although here, they gave the students a bit more structured task when asking them to rank the pitches. But this was because they wanted the teacher to have a suitable range of observations in order to illustrate the concept of frequency. A clear cut genetic-inductive approach is found in the presentation of group 3. They really started from *what is heard* when more and more water was poured in the glass, keeping the energy input constant. The teacher also pointed to sense experiences like the "inertia" of the sound and that it gets "slower" when the pitch gets lower. However, from that experience the teacher jumped to the notion of "number of oscillations" without explaining where the notion of oscillation came from. Another teacher in the same group broke the genetic-inductive approach by claiming that the students need to get a "feeling for the concepts": They should know what frequency and decibel are about, before they can investigate the phenomenon themselves, in order not to get confused by seemingly contradictory observations. The three remaining group presentations had no clear approach to solving the task. Group 4 seemed to be hindered by the fact that they could not explain or understand why the pitch is going up when water is added in a bottle, but down when added in the glass. As long as they themselves did not understand it, they were not encouraged to let the students investigate it. Both group 5 and 6 tried to employ the genetic-inductive approach, but the bridge between perceptual experience and scientific concept was not made explicitly clear. In their exploration of the bridge, group 6 had merely started with the practical entrance into investigating the phenomenon. They had not, however, started to link this with chosen scientific concepts.

In regard to the two bridges (figure 1 and 2) there seems to be a certain logical connection between each of the steps. In the bridge towards decibel (figure 1) the teacher directly linked the pressure, with which the sound is produced, and the input energy. The amount of energy was further related to the height of the waves on the water in the glass. Thus, there is a perceptual connection between the changes in the *seen* wave heights and the *heard* sounds. The observed difference in heights is directly related to the concept of amplitude, consequently leading to the concept of decibel. In the other bridge (figure 2) "swingings" were easily envisaged as vibrations; and vibrations can be regarded as waves. Actual waves were also seen in the water contained in the glass when it sounded. Now, waves can have different "speeds", but the final link between the notion of "wave speed" and that of frequency is a bit ambiguous. "Wave speed" refers to the speed with which the wave moves through the medium (air), which is the same for all sounds, whereas frequency has to do with the pitch of the sound. On the other hand, it could also be said that the "quicker" the wave the greater the number of waves per unit of time – hence, frequency. A second weakness in this bridge is that the starting point, "something which goes round and round", cannot be generalized to all sounds, but

is an effect of the finger moving round and round on the rim of the glass. Hence, even though the bridge attempts to visualize logical connections between each of the steps, it does not give an accurate and general exposition of how the concept of frequency connects to sound phenomena.

In some of the presentations the pre-service science teachers introduced intermediate notions, notions which had the function of connecting one concept to another. “Energy” and “pressure” in figure 1 are examples of such notions. Although few in number these attempts indicate a potential field of developing teachers’ ability to engage in the genetic-inductive approach to science teaching.

The results show that the science end of the bridges was wider in the sense of being quantitatively more prevalent in their planned lessons than that end of the bridge which rested in sense perceptual lifeworld experience. This was in spite of the fact that non-scientific, more or less imaginative associations were more prevalent in the outcomes of the first exercise, described above. This conclusion points to the need for science teachers to develop the courage to use their own and their students’ immediate perceptual experiences as “raw material” for phenomenological reflections and for building that end of the bridge which rests in the perceptual lifeworld of our common human experience. That so many of the teachers wanted to start their lessons by *first* introducing the scientific concept and *then* moving on to sense perceptual exploration suggests a need to liberate their perceptual sensibilities from preconceived scientific concepts. This might help them realize the educational potential of more imaginative associations and expressions of sense experience.

The results further show that these teachers only to some extent applied their own multifaceted descriptions of the sound phenomenon to link the perceptual and the conceptual sides of the bridge. This is most likely due to a lack of training, both in phenomenological observation and in the genetic-inductive approach to teaching science.

Developing the Ability of Unfolding Lifeworld Phenomena

This exercise on sound intends to connect sense perceptual experiences with some chosen concepts (frequency, decibel and noise), thus taking for granted that science teachers actually have the ability of careful listening. Although the phenomenological approach to science education had been introduced to teachers, they cannot be regarded as experienced in phenomenological observation and description. We are aware of this fact when drawing conclusions from the study. Following the idea of Husserl we might say that this listening exercise has two intentions: first, it attempts to bring the phenomenon to “pure expression” (Husserl 1970, p. 166), secondly, it attempts to ground the concepts - by students often experiences as “mere words” - in the perceptual experience. The first aim essentially implies unfolding the phenomenon through open and unprejudiced observations. This attempt is in line with Husserl’s early phenomenology and its demand of unfolding the essence of the phenomenon by carefully describing it:

This phenomenology must bring to pure expression, must *describe* in terms of their essential concepts and their governing formulae of essence, the essences which directly make themselves known in intuition, and the connections which have their roots purely in such essences (p. 166; italics in origin).

The second aim of the exercise is actually more related to the illustrative-deductive approach as it starts with the scientific concepts and uses a particular sound phenomenon as means in order to give life to these concepts. How do we as science teachers gain access to lifeworld phenomena? Is it by an open and unprejudiced attitude, as Husserl in his early works suggests as a method for bringing

the phenomenon to pure expression? Or is it also - even though intending to meet the phenomenon openly - due to their knowledge giving them a *pre-understanding* of perceived phenomenon? According to Ströker (1987)

...in the popular version of Husserl's 'turn' to the life-world lurks the danger of misinterpreting not only Husserl's last work [*Crisis*], but even his phenomenology as a whole. *The life-world* as it is situated in Husserl's problematic of the foundation of science is *not just the world of every-day life* with which we are immediately concerned., Rather, to gain access to this life-world *we must begin with an already constituted science and inquire back* into the ground of its claims to validity. (p. 13; our italics)

Ströker's argument turns the order of our reasoning so far the other way around. Instead of *starting* in perceptual phenomena of the lifeworld, these phenomena should be the *end* of our questioning "back" from scientific concepts into our original experience. For us as teachers, the task is to find the way back from science to immediate experience, in order *then* to walk this bridge again, together with the students, but the other way, from experience to concept. The challenge of being a science teacher is to develop this ability, which necessarily includes the development of a rich perceptual lifeworld and to communicate these experiences.

The building of bridges between lifeworld phenomena and scientific concepts is seldom if ever complete; each bridge is provisional and often has to be crossed again and again, in order to test its viability. However, it seems that science teachers are often content with having established their own "science end" of the bridge and then calling for the students to cross the bridge, without realizing that the bridge at the other end is very loosely connected to "the ground"; that is, to the human sense perceptual lifeworld. Therefore, few pre-service teachers, as showed in this study, dared to enter the bridge with confidence.

Concluding Remarks

The phenomenological approach to learning is basically skill oriented. Learning becomes a two-sided process where perceptual as well as cognitive skills are trained and fostered. These skills are always trained in relation to concrete phenomena, phenomena which are chosen as points of departure for science lessons. This, however, does not mean that concepts can be conjured out of "pure" sense experiences. Every bridge building starts from both sides. As the science teacher students in this study show, the bridge between the phenomenon and relevant concepts is built by approaching the phenomenon in an open manner and simultaneously applying already gained knowledge to the actual sense experience. Thus, understanding concepts of sound is closely related to a sensibility of the sound phenomena; that is, the ability of listening. In school, this sense ability is often taken for granted – the *real* problem is taken to be the students' cognitive understanding of relevant concepts such as frequency and decibel.

A phenomenological critique of current science education points at a profound lack of sensibility for the natural world surrounding us. In this approach to science education reasoning about the nature is based on rich perceptual lifeworld experiences; reasoning about sound is based on both the ability of careful listening and the consciousness that sound is part of students' lifeworld experiences. Husserl's imperative to return to "the things themselves" calls upon us to develop our sensibility to the multiple expressions of nature: "It is as if nature has a hundred languages, but we have become

deaf to ninety-nine of them. In order to (re)discover these languages, we have to intentionally and attentively explore all aspects of sense experience” (Dahlin, 2001, p. 454). This intentional exploration of sense experience is the first step in a phenomenologically based science education.

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