Changes in Primary School Pupils' Conceptions of Water in the Context of Science, Technology, and Society (STS) Instruction

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Introduction

The conceptual change approach has had a significant role in the research of science education, and its implications for teaching and learning are frequently discussed (e.g., Howe, Devine, & Tavares, 2013). Conceptual change studies aim to analyse the knowledge construction and conceptual growth processes in learning situations, and several theoretical strands, such as epistemological, ontological, or social/affective, have been formulated to assess the conceptual change process (Author, 2005; Duit & Treagust, 2003). At the same time, the recommended aspect in current school learning and geography learning relates to the question of how intensively 21st century skills and societal issues are recognised as part of science education (see Pauw, 2015). The significance of science in societal activities, the role of socio-scientific issues in ethical decision-making, and the socio-economic status of science learning have been seen as significant in terms of pupils’ motivation and learning outcomes (e.g., Gresch, Hasselhorn, & Bögeholz, 2013). Water phenomena are undoubtedly societal phenomena in several ways, but pupils’ understanding and conceptions of water use can be fragmented, limited, or rooted in everyday concepts (Çoban, Apkinar, Küçükcankurtaran, Yıldız, & Ergin, 2011; Reinfried, Aeschbacher, Kienzler, & Tempelmann, 2015), and they have not been widely recognised under the lens of conceptual change approaches. In this paper, we consider learning settings in which pupils study water phenomena, including elements of the scientific, societal, technological, and environmental significance of water. In the study, Science, Technology, and Society (STS) instruction was applied as a learning
context when studying water phenomena from the perspective of conceptual change with primary school pupils. STS instruction provides the opportunity to analyse pupils’ conceptual change as an individual learning process in contexts in which personal, societal, and global issues are incorporated into the learning process, to assess how the process fosters their behaviour and understanding of sustainable life.

**Conceptual Change in Relation to Water Phenomena**

Conceptual change research (Posner, Strike, & Hewson, 1982) was originally based on pupils’ epistemologies, and it considers conceptual change as an individual and cognitive learning process. Epistemological changes focus how pupils see and define their knowledge and information, and the studied concept should have intelligibility, plausibility, and fruitfulness in order for conceptual change to occur (Posner et al., 1982). Some researchers have extended the definition to include both epistemological and ontological changes, referring to how pupils see the world as a whole, and concepts are established in terms of their nature; for example, materials and processes are seen as different from each other in a metaphysical sense (Chi, Slotta, & Leeuw, 1994). According to these above-mentioned models and many others, conceptual change is often defined as a two-dimensional cognitive process in which changes in conceptions are either weaker or stronger in terms of knowledge structure.

A cognitively orientated but multiple phase analysis was built up by Thagard (1992), who discusses the degree of conceptual change over nine stages, rather than with just the concept of lower- and higher-level changes. His classification for the conceptual system is derived from the network structure of the concepts, which can be understood as a complex computational structure organised into kind hierarchies, part hierarchies, and rules for problem-solving (Thagard, 1992, p. 34–35). Kind hierarchies refer to changes like belief
revision, concept addition, and simple reorganisation of conceptual hierarchies. These first three levels are common in conceptual development. Part hierarchies are more challenging and require movement from one concept to another. The advanced levels of conceptual change (levels 7–9) provide new rules of problem-solving, and the conceptual hierarchies emerge in the knowledge structure. This means that concepts are reorganised like jumping from one branch to another, creating a new kind of hierarchy. At a higher level, so-called tree switching also occurs, which not only reorganises the conceptual hierarchies, but also changes the meaning of classification (Thagard 1992, 36) (see Table 1).

Thagard’s model sounds relevant in the analysis of young learners’ conceptual change process, because it provides a variety of stages to focus on different developmental phases of knowledge construction. Very often in previous water-related studies, pupils’ conceptions (Reinfried et al., 2015) are difficult to change and changes are impossible to analyse only on a dichotomy scale. In his model, Thagard follows a very similar cognitive approach to conceptual change to several other researchers, leaving out the learning contexts and interaction with learning materials and methods. However, the concepts are significant in physical geography, and the context and learning environment matter (see Reinfried et al., 2015).

Halldén (1999) sees conceptual change as context dependent, and he recommends focusing on the discussions and settings during the studying process. His view of conceptual change becomes extended in comparison to pure cognitive models, and the factors that relate to the process of conceptual change can be analysed as context based. One problem of conceptual change among pupils is identifying adequate theoretical contexts for the
interpretation of concepts taught at school. Halldén’s (1999) view of conceptual change includes the component of cognition, but also refers to factors that exist externally in conceptual change contexts, such as situational and cultural contexts, including values and experiences. In recent years, his model has been applied to current empirical studies, in which theoretical context, theoretical concepts, and empirical context build a coherent forum for considering learning processes (Larsson & Halldén, 2009). Österlind and Halldén (2007) have applied Halldén’s views to empirical research on freshwater pollution. According to these empirical findings, the pupils contextually interpreted the theoretical concepts. Pupils’ understanding was strongly linked to concrete findings using their senses (Österlind & Halldén, 2007). Hence, pupils’ conceptual change processes are made within conceptual contexts, as well as within the contexts where concepts are described or explained (see Larsson & Halldén, 2009).

The existing conceptual change research has mainly addressed the fragmented science concepts rather than considering the science phenomena multidimensionally, including specific contexts. Water-related concepts such as sinking and floating, or buoyancy, have been analysed in several studies (Author, 2005; Kawasaki & Herrenkohl, 2004; Turcotte, 2012), as have evaporation, boiling, and condensation (Tytler, 2000; Varelas Pappas & Rife, 2006), and, more recently, water pollution (Österlind & Halldén, 2007) and ground water (Reinfried, 2006). According to these previous water studies, pupils’ pre-conceptions are rather stable and difficult to change during short school learning projects. Several strategies have been applied to school contexts, and the challenges are rather similar: changes are often epistemological, and more emphasis on ontological changes is needed. Studies have not always been conducted in real-life contexts, and the outcomes have limitations in normal school learning (Duit and Treagust 2003).

The context-related conceptual change approach could enable teachers to support the
pupils’ conceptual change process in scientific understanding, and to develop pupils’ ideas that have meaning and significance in their lives (Sadler, 2009). In the field of cognitive science and conceptual change, it has been recognised that when pupils derive their school learning from their everyday lives, and make connections to personal and social environments, authentic and inclusive learning is achieved (see Wee, 2012). This perspective has been missing in the area of conceptual change, which, in a sense, has been a significant research area in the development of science instruction.

**STS Instruction as a Context for Conceptual Change**

STS instruction considers science content from societal, scientific, environmental, and technological perspectives. STS instruction can be seen as an appropriate approach for those content areas that are closely and concretely contextualised in pupils’ everyday lives and include clear connections to broader societal, environmental, or technological viewpoints, while at the same time referring to societal life and decision-making. STS instruction encourages pupils to raise questions and express doubts and justifications to find links between their everyday experiences and more global considerations. In STS instruction, the teacher and learners together raise questions to consider scientific phenomena as meaningful for their lives. In a study by Byrne, Ideland, Malmberg, and Grace (2014), primary school pupils engaged in socio-scientific discussions and were able to argue about complex environmental phenomena from several societal perspectives. Previous studies (Çoban et al., 2011) have revealed that, to promote pupils’ conceptions of water and understanding of invisible systems, there is a need to organise study contexts in which these issues are concretely considered.
Research Questions

In contrast to several previous conceptual change studies, this research considers water issues following STS instruction in authentic classrooms. Thus, it is relevant to consider the changes in pupils’ conceptions not only as an individual process of conceptual development but as context-related. We aim to recognise when different learning contexts provided in STS instruction are related to changes in pupils’ conceptions. Pupils’ conceptions are analysed prior to and after the STS instruction, and their conceptual change processes are referred to in the existing models of conceptual change by Thagard (1992) and Halldén (1999). The following two research questions will be considered in this paper:

What are the pupils’ conceptions of water before and after the STS instruction?

How can pupils’ conceptual changes be understood in relation to Thagard’s (1992) degrees and Hallden’s (1999) models of conceptual change?

Methods

This research examines pupils’ conceptual change process when studying water in STS instruction. This study follows the case-study design (Yin, 2009) and involves fourth- and fifth-graders aged between 10 and 11 in a rural primary school in Finland.

Essays and Interviews as a Method of Data Collection

Before instruction, pupils were asked to write an essay about the issues that came to mind when they thought about water. The class teachers instructed the pupils to write an essay entitled “water around us”. The pupils had one lesson (45 minutes) to write their essays. The following week, the selected pupils were interviewed to capture the reasoning
and justification for the issues expressed in their essays, and to verify their views and understanding of the main water-related concepts.

Essays reveal pupils’ conceptions through their own individual ways of describing and interpreting issues in a particular context (Ellis, Taylor, & Drury, 2005), and the researchers were not able to influence the descriptions. In addition, essay writing supports interpretation, as the scientific phenomena are related to some particular context, making descriptions concrete and situated. However, the descriptions depend on the pupils’ conceptual abilities to describe their perceptions. If pupils cannot produce fluent and valid essays, they might be misunderstood (see Robertson, 2004). Hence, interviews were used once during the process to verify the pupils’ descriptions and improve the validity of the analysis. Forty-one pupils participated in both the pre-writing and post-writing phases.

Individual interviews were conducted one week after essay writing, before and after the instruction. Through the interviews, the researchers attempted to gain explanations for pupils’ descriptions or arguments in their essays. In addition, the water-related phenomena or concepts that were not discussed in the essays, such as ground water or surface water, were taken into consideration in interviews to expand the pupils’ conceptual understanding.

Based on an analysis of the essays, 10 pupils were selected for interviews, following the criteria of advanced- and low-level descriptions and/or reasoning in the essay. Five pupils with advanced and multidimensional ways of writing about water were selected to be interviewed. The advanced-level pupils described water phenomena through several contexts and were able to consider water from several perspectives, with a developed understanding of water. In addition, five pupils who were not able to elaborate water phenomena, and who rarely had multiple and scientific views of water, were interviewed.

Aims and Content of Instruction
After the pre-phase of writing essays and interviews, pupils participated in instruction conducted by class teachers and Master’s level teacher students of science and technology education with specific competence in these issues. Nine graduate student teachers supervised the first group of fifth graders (case 1, 26 pupils in total), four student teachers supervised the second group of fifth graders (case 2, 25 pupils in total), and four student teachers supervised the fourth graders (case 3, 16 pupils in total). All the groups had four double lessons, each lasting 90 minutes. Pupils conducted short water-related problem-based experiments, participated in inquiry-based activities, and visited a water purification station (see Table 2 and Table 3).

[Insert table 2 and 3 here]

The aim of the lessons was also to improve the pupils’ abilities to share their knowledge and to discuss their perceptions and experiences of water. The socially shared knowledge construction process was documented individually in separate water project workbooks designed for this purpose. The teacher’s role was to elaborate on and conceptualise the phenomena, to foster the process of conceptual change.

Data Analysis

Content analysis (see Krippendorff, 2013) was chosen to analyse pupils’ essay and interview descriptions, to identify the contents of pupils’ descriptions connected to water and the variance in their understanding. After coding all fragmented and context-related descriptions in the data, the authors individually constructed the primary coding schemes for the data. In the second phase, the initial coding schemes were compared and agreed, to verify the analysis process. The analysis was inductive, but, in the final phase, the codes were reviewed in regard of the STS categories: science, technology, and society. The main categories were entitled life-related aspects, environmental interconnections with water,
physical and chemical properties of water, and technology related to water. In the data, the environmental perspective became evident, and this was taken into consideration. The frequencies of each category were counted, and a quantitative comparison was produced (presented in Table 4).

For the second research question, the changes between pre- and post-assessment were considered, along with models of conceptual change. First, Thagard’s (1992) degrees of conceptual change (see Table 1) were reviewed with the data, thereby explaining the pupils’ conceptual change process.

In addition, the data was interpreted using Halldén and his co-authors’ (Halldén, 1997; Österlund & Halldén, 2007; Larsson & Halldén, 2009) model about the contextualised process of conceptual change. Conceptual changes may occur in different contexts, including situational contexts, cognitive contexts, and cultural contexts, and therefore, processes can be understood and explained through different contexts. In this paper, we identify how the pupils’ STS instruction experiences can be noted in their conceptions after the study, and how different contexts become part of their conceptual change.

Results

Pupils’ Conceptions of Water-Related Issues Before and After STS Instruction

Generally, the pupils’ conceptions changed from general, everyday issues to specific aspects of water use. The frequencies of discussed categories (see Table 4) show that cursory themes, such as water use in daily activities and water in life in general, reduced during the study process. Instead, scientific and environmental perspectives increased.
Prior to the study, pupils mostly associated water with its importance for human beings and everyday activities. Pupils considered water an element or substance used for human needs such as drinking and washing. In addition, water use for recreation, like swimming, was mentioned systematically. Water was widely described as a basic, self-evident element of everyday life.

Prior to the instruction:

**Essays:**

“You can swim in water.” “Cleaning comes to my mind from water.” (girl 27, 5th grade)

“You cannot live without water because we need to wash our hands, take a shower and drink. Actually we need water for everything.” (girl 16, 5th grade)

**Interview:**

I: “How else can people use water than for drinking?”
P: “It can be used like washing and dishes.”
I: “Yes.”
P: “And it can be for swimming.”
I: “Yes.”
P: “In the summer.”
I: “Yes.”
P: “I do not know more. Then it can be used as an energy source.”
I: “Yes, water can be used as an energy source. Do you know how it can be used?”
P: “Electricity can be achieved from watermills.”
I: “Yes, yes, and something else?”
P: “Hmmm, no, I do not know more.”

(P3: Eric R1.txt-3:8)

After the study, pupils’ expressions focused on water consumption at personal and societal levels. The pupils considered how they use water themselves, for example for showers. Fishing was mentioned often. It seems that the project experiments were rather notable for them to understand the consumption of water. The more broad societal aspect was considering water consumption for energy use.

Besides everyday life, pupils focused on the biological relations of water. Biotic relations were systematically taken into consideration in all the data. Water was seen as playing an essential role in life and its varieties, such as human beings, plant growth, and a living environment for animals. In general, the pupils described how water is needed for the
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maintenance of life. However, prior to the study, pupils were not able to explain why water plays such a significant role in life. In addition, few abiotic elements, such as stone, sand, the sun, and the sky, were mentioned in some essays, but those were not linked to any processes. Only water purification from sea water was linked to the separation of salt (vaporisation).

After the instruction, the biotic relations were more specific. Similarly to prior to the instruction, water was related to the life of plants, animals, and nature in general, but in the interviews, human needs were rarely considered after the instruction. Reasons for water needs, such as growth and photosynthesis, were defined. After the instruction, water was considered as an abiotic element more accurately, and was also associated with the water cycle.

After the instruction:

Essays: “Without water we do not have plants or life on earth. Human beings need water every day.” (girl, 5th grade)
“Water is an important liquid for human beings, plants and animals. [...] Water is important for all life.” (girl, 4th grade)

Interviews: I: “Why is water needed in nature?”
P: “Plants need it for photosynthesis.”
I: “Yes.”
P: “And all animals need it as much as humans”.
I: “Hmm, yes. If we do not have water here?”
P: “We will not manage.”

(Water as a chemical subject and water states were recognised prior to the instruction in some essays and interviews, but the concepts were understood poorly. Concepts such as ice, snow, liquid, solid, gas, and steam were used incoherently, and water characteristics were derived from everyday descriptions such as colour and odour. In addition, the states of water were not reasoned clearly; mainly, pupils justified the states based on the climate and seasons. Only one pupil reasoned it according to changes in temperature.

Prior to the instruction:
Essays: "It is wet and heavy, there is oxygen in water." (girl, 5th grade)

Interviews: P: "Water can be wet, warm or cold."
I: "How could you describe water to somebody?"
P: "I would say that it is wet and cold or warm depending on the season.”
(Wilhelmina1.txt.20:12-13)

After the instruction, the pupils did not describe the chemical characteristics of water significantly better. Chemically, water seemed to be rather complicated to pupils. In those few cases in which pupils’ conceptions indicated some changes, water was defined as a chemical substance, like a liquid, with several characteristics, such as runny, damp, and flavourless. Only in a few cases were chemical models mentioned or drawn and explained. In addition, water was described as a subject that follows physical laws, such as Archimedes’ law.

After the instruction:

Essays: "Water consists of molecules, where one is an oxygen atom and two hydrogen atoms. Its chemical expression is H₂O. Water has 3 states: solid, liquid and steam…” (girl, 5th grade)

Interviews: I: “How could you describe water?”
P: “It is runny. It does not taste. Hmmm. Nothing else.”
I: “How about smell?”
P: “It does not smell?”
(P2 Anton2 -2:15)

Pupils considered water widely in a geographical manner. Prior to the instruction, the pupils particularly mentioned geographical places where there is a shortage of water, and how the amount of water varies in different parts of the earth. The water location was sometimes linked to societal issues, humanitarian work, and water rationing. However, the reasons for the unequal distribution of water were unknown in the interviews.

Prior to the instruction:

Essays: “Most of earth is covered by water.” (girl, 5th grade)
"There is not enough water in the desert and Africa.” (boy, 4th grade)

Interviews: I: “Do we have similar water on the Earth? The same amount everywhere?”
P: “No.”
In the interviews, surface water and ground water were discussed. Prior to the
instruction, the pupils were not able to define surface water or ground water, and often
understood that surface water was on the surface of a lake or river, and ground water was at
the bottom.

In the essays prior to instruction, pupils wrote about water distribution on earth from several
perspectives, but after the instruction, they mainly wrote about the lack of water. In addition,
after the instruction, there were fewer geographical considerations, but they were broader and
more specifically reasoned. Water was seen in different places, such in forests or lakes or in
the ground. In addition, ground water and its relation to geographical locations was more
systematically explained in post-instruction interviews.

After the instruction:

**Essays:**
“In different countries there is different amount of water: in the desert there is lack of
water and hence no possibilities for many plants to live. However, in rainforests there
is water and lots of plants.” (girl, 5th grade)
“In some places there is too much water and places lack it. The reasons are flood
(because of raining), volcanic eruption and tectonics.” (boy, 5th grade)

**Interviews:**
I: “Where you can find water?”
P: “From forests, of course lakes.”
I: “Hmm.”
P: “And from bog.”
(P5: EmilyT2.txt -5:13)

Prior to the instruction, water was rarely linked to environmental protection or
pollution, and only water purification was discussed in interviews. The pupils were aware
that water can be polluted, but they could not describe the reasons for the pollution. Neither
were they able to describe or explain water purification processes. A few pupils mentioned
some water purification methods, such as using chemicals and filtering. Water rationing was not seen as relevant in society or in their personal lives.

Prior to the instruction:

Essays: “When water becomes polluted, it should not be drunk.” (boy, 4th grade)

Interviews: I: “Do we need to save the water?”
P: “Hmm, yes, if there is a lack of water in some period, if water is not available in two hours, it is good to store it.”
I: “Hmm.”
P: “But there are no other reasons to control use of water.”
I: “So you think that we have water enough here in Finland?”
P: “Yes, we do not have to save at home.”
I: “Ok, don’t have to save.”
P: “Yes, but I do not know if it is necessary somewhere else…”
(P20:Wilhelmiina1.txt- 20:20)

After the instruction, pupils more systematically referred to environmental questions, but they did not refer to as many details as they did prior to the study. The water purification process was clearly explained, and different phases of the process were taken into account.

The significance of ground water and surface water were explained and reasoned in different contexts. In addition, the lack of water was considered systematically after the instruction, and water control was discussed and associated with their everyday behaviour.

After the instruction:

Essays: “Water will be polluted, if people throw /drop litter.” (boy, 4th grade)
“Water purification stations purify water for us. After that, water travels to water towers and will be delivered to houses with tubes.” (girl, 5th grade)

Interviews: I: “How could you clean water?”
P: “First, it was a mechanical phase in which the biggest litter is collected.”
I: “Hmm.”
P: “And then a biological phase in which good bacteria will be added. The bacteria will decompose impurities, and then comes the chemical phase.”
(P1: August2.txt. -1:10)

In summary, pupils’ initial conceptions of water were situated in regard to their everyday lives, and pupils considered their water use subjectively. They knew that water is a core substance in their lives and in the world in general, but they considered it to be self-
evident and could not explain or reason their conceptions. Only a few pupils were able to link water to societal or environmental questions before the STS instruction. After the instruction, the pupils explained and described water-related concepts and processes more accurately. Their perspectives became conceptually more organised, and they were able to consider causes and consequences. In addition, scientific and societal issues, such as chemical composition and water purification, were explained after the instruction.

**Conceptual Change in the Context of Theoretical Approaches by Thagard (1992) and Halldén (1999)**

In this data, the pupils’ conceptual changes matched the first five degrees of conceptual change by Thagard (1992). Nearly all the children added some new instances of water use in terms of their everyday lives. After the instruction, they had more empirical examples of water use and water location. There were several indications about the reorganisation of conceptual hierarchies, such as adding a new strong or weak rule. Prior to the instruction, the pupils were not able to consider water in the process of water purification. After the instruction, many pupils considered water use to be part of water purification, and were able to explain the purification methods. This part of conceptual development provided the pupils with a new rule explaining water use in everyday life and the solutions to the problem of a lack of ground water.

According to Thagard’s degrees, “part relations” focuses on the creation of new part relations of the concept under learning (Thagard 1992, 35). In this study, the pupils became aware of the chemical construction of the concept. After the STS instruction, some pupils were able to analyse the chemical structure of the concept and thus develop their scientific understanding of the concept, which can be seen as a new part-relation, chemical expression,
of the concept. However, scientific understanding of the chemical structure of water remained narrow.

After the study:

Interview:

I: “Did you talk about the chemical structure of water?”
P: “Yes, it is H₂O.”
I: “Oh, what does that mean?”
P: “So it is like two oxygen and then one hydrogen.”

(P1: August2.txt -1:15)

In addition, in the case of water states, epistemological changes occurred for the pupils. Prior to the instruction, the pupils often recognised one or two states of water, but afterwards they fluently described all three states; solid, liquid, and gas. In addition, the states of water were linked to the water circulation process in nature. The process of water circulation and consideration of water states provided a new kind of relation for their conceptions.

Thagard (1992) sees in his model that the four highest levels are associated with the conceptual revolutions that need the rejection of existing explanations and a move towards new, more proficient explanations. In this study, several pupils received the explanatory power of the concepts of ground water and surface tension. The definition of the concepts became clear for the pupils during the instruction, and they linked the concepts with water purification, pollution, and water control. Hence, the understanding of ground water and its appearance supported the pupils’ understanding of water-related phenomena more widely.

In addition, the process of water circulation became more evident for the pupils in this study. Prior to the instruction, pupils recognised the processes but were not able to explain them. After completing the kind relations of the concept (solid, liquid, gas), the water circulation process was explained and linked to geographical locations and a lack of water. Again, the explanatory power (see Thagard 1992, 254) increased and brought the pupils’ explanations to another level. The changes in these processes refer to the seventh level, collapsing part of a kind hierarchy, in which the strength of the rule increases to the point that the new explanation becomes stronger than the existing rule in the conceptual structure.
Halldén’s (1999) model refers to the role of contextual knowledge, such as how conceptual changes emerge. After the instruction, fifth-grade girls in particular explained water-related phenomena from societal perspectives, such as the history of water and its meaning for life and for human beings. The girls changed their earlier perspective of considering the water around us; there were clear movements from their situational everyday life contexts towards more global societal contexts, and trying to explain the existence of water or its appearance in scientific contexts. After the instruction, the pupils did not only consider water in their personal life contexts, but they also considered water more globally by linking it to environmental and geographical aspects of water occurrence.

After the study:

Interview: P: “In some places, the water is cleaner and in some places not so clean. For example, in the areas where people use lots of cars, there is more pollution, and water becomes polluted easier. Cars make more exhaust smoke, and it pollutes water as well.”
(P5: Emily T2.txt.-5:19)

In general, there are implications to linking scientific concepts (states of water) to environmental and societal contexts such as water circulation. The pupils were able to explain changes in temperature in different parts of the atmosphere, and consequently they were able to explain water circulation in the environment. In addition, pupils’ understanding of the concept of ground water changed when they linked it with the water purification process and were able to see how water purification proceeds at water stations and in nature. An explanation of processes is often needed to connect the different contexts, such as scientific and situational contexts of consideration, and to direct pupils to consider the phenomena from societal perspectives.

In summary, the pupils’ conceptions of water changed during the STS instruction. The context of studying provided different paths for conceptual change (see Table 5). Lower-level changes happen in situational contexts through both new instances and weak rules of
understanding water phenomena. More advanced changes require the reorganisation of concept understanding and integration into different contexts. A higher-level conceptual change process needs more explanatory power, which seems to be created through the experience of different contexts of learning.

Change in pupils’ conceptions of water is not a linear process in which the degrees of conceptual change occur systematically. This means that some conceptions are more advanced than others and developed to a higher level, revealing the links between concepts and contexts. In addition, the different contexts have different roles at each degree. To support the pupils’ conceptual change process, the studying process should provide several viewpoints for pupils to pick up those aspects that are relevant for them at that time, and that support their own cognitive degrees and contexts (see Halldén, 1999).

Conclusions and Discussion

This study aimed to foster pupils’ understanding of water-related phenomena when using STS instruction. The focus was especially on scientific, technological, and societal aspects of water use and water appearance. Fourth- and fifth-grade (age 10 and 11) pupils already had some knowledge and conceptions about water, which were analysed as a starting point for learning and conceptual change. Prior to instruction, pupils’ ideas of water were fragmented and descriptive. In this sense, the study results follow the tendency of previous studies of conceptions of water (see e.g. Reinfried et al., 2015). Pupils had some detailed knowledge of water-related issues and were closely focused on their everyday life contexts. They described water from several perspectives but could not reason about or justify the phenomena. Pupils
rarely considered water from different contexts, focusing mainly on everyday use and geographical contexts such as water appearance.

After the instruction, some aspects of water were still fragmented and not fully understood, but most of the pupils were able to change their conceptions. With several issues, such as water circulation, water purification, and the role of ground water, pupils were more coherent, and their descriptions had more explanatory power. They were able to explain their conceptions and find cause-reason relations for many water-related phenomena. However, clear higher-level changes occurred only with certain pupils. This tendency is similar to that noted in previous studies, in which a quarter of pupils do not improve their conceptions at all (Reinfried, 2006), indicating the slow process of conceptual change.

Although there are limitations to evaluating the role of teaching approaches, including a lack of experiment-control groups, this study provided an opportunity to consider the conceptual change process in authentic learning contexts within the regular curriculum. STS instruction provided a framework to analyse the conceptual change process as a context-dependent process in which several issues and variables stimulate conceptual change at the same time. Thus the study adds a new viewpoint to the previous studies considering conceptual change in water-related concepts (e.g. Reinfried et al., 2015). The STS instruction considered water phenomena in situational contexts, in cognitive contexts, in cultural contexts, and in scientific contexts, and the contexts were involved in pupils’ conceptual change processes, with different effects on different pupils.

This study provided pupils with several learning contexts in which to reorganise their existing conceptions or to complete their understanding of emerging ideas of water-related phenomena. In the scientific context, for example, a water states experimental test was conducted. Pupils found the approach motivating and mentioned it systematically in their essays, but the approach did not provide significant changes to the pupils’ conceptions. The
progression from pre-conceptions to new, clearly revised conceptions was not clearly shown. This may be because scientific experiments done in classrooms are rarely well associated with contexts in which issues become significant or meaningful for primary-age children, and thus do not cause dissatisfaction with current ideas (see also Howe et al. 2013). Österlind and Halldén (2007) reported similar findings in a case of learning about freshwater pollution. They argue that one of the main challenges in science learning is that pupils do not see the relationship between theoretical concepts and the empirical world. Empirical experiences are difficult to explain in a theoretical context, and vice versa. Classroom experiments should also produce dissatisfaction between existing and learned conceptions, to foster conceptual change and to provide supported contexts for considering issues meaningfully.

However, environmental issues, such as water purification and water circulation, with the role of ground water, became more significant in pupils’ conceptions after the instruction. Pupils explained water use and appearance, linking these aspects more systematically, and they were able to create more holistic and environmentally broad conceptions of water use. Pupils’ descriptions of the role of ground water in terms of water control and water purification became clearer. The approach to how pupils considered the use of water and its meaning for human life on earth became more common and global than it was before the instruction. As mentioned above, the scientific context discussed in the classroom did not become apparent, but societal questions, which were more clearly considered in everyday contexts (newspapers, visits), produced a clear change in pupils’ ways of thinking about water and its role in related phenomena. The STS instruction had an environmental component with scientific, societal, and technological aspects, and it guided pupils’ conceptions to coherent and multifaceted views of water in general.

This study provides several good examples for arguing that the conceptual change process is a context-dependent process. As Thagard (1992) has mentioned, the last phases
occur rarely, and we could not recognise any branch jumping or tree switching in this present study. It is likely that this STS instruction period was, again, too short to redefine all water-related misconceptions and to build theoretically coherent conceptions of the phenomena. The reconstruction of concepts happens more clearly in cases where scientific concepts are linked to different contexts in real life, and those are discussed through the processes that are linked with different contexts. Therefore, the pupils’ conceptual change process is not a straight line from everyday conceptions to scientific conceptions, including the power of theoretical explanations, but rather moves towards scientific conceptions through context-dependent explanations using scientific concepts. The use of appropriate concepts (scientific concepts) needs support from several contextual situations, which enhance pupils’ conceptual understanding. The different contexts provide varying exploratory power for each learner.

References


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