

## **Primary school pupils' perceptions of water in the context of STS study approach**

Sari Havu-Nuutinen • Sirpa Kärkkäinen • Tuula Keinonen

*Received 10 April 2010; Accepted 10 September 2011*

This paper focuses on pupils' perceptions of water issues. The instructional situations take place in a Finnish primary school and aim at introducing the Science-Technology-Society (STS) study approach. The primary aim of this study is, in the context of STS instruction, to describe issues that pupils associate with water. This paper involves fourth and fifth graders from a rural primary school in eastern part of Finland aged between 10 and 11 ( $n=52$ ). Pupils were asked to write down the issues that came to mind when they thought of water, both before and after instruction. In addition, in the beginning of the process, pupils were asked to draw something about water. After the first set of writings and drawings, pupils participated in a teaching and learning process, which was supervised by master level teacher students. Prior to this process, pupils mostly associated the role of water for human beings, with drinking and washing as well as recreational pastimes such as swimming and fishing. The issues in this process varied from scientific to environmental protection, although the pupils' perceptions were very limited. After instruction, pupils wrote about the meaning of water in more general terms, relating to science, technology and societal issues, including the idea of the water cycle. This study increases and broadens researchers' and teachers' knowledge of pupils' ideas and thoughts about water in an authentic school context. The study focuses on water issues in science, society and technology and aims to support pupils' understanding towards becoming more systemic, multidimensional and critical. Environmental and science education are enriched with technological issues and this study reveals the challenges of integrated instruction. Methodologically, the study discusses the role of essays and drawings in interpreting the research results.

**Keywords:** perceptions of water, STS instruction, drawings, writing essays

### **Introduction**

#### *Pupils' Understanding of Water*

Although water is one of the subjects which is included in most science education curricula all over the world, pupils' perceptions, ideas and conceptions of water have not been studied widely. According to current research, pupils do not understand water's significant role in life (Ben-Zvi Assaraf & Orion, 2005). Current environmental and science issues such as climate change, sustainability, natural diversity and pollution, are very strongly linked to the questions of water resources, their effect on life itself, the life cycle and on human beings. Water issues are not considered very systematically in school and concentrate rather on subject specific aspects. This

results in pupils failing to see how water issues relate to each other (see for example Shepardson et al., 2007). In addition, many scientific studies focus only on particular aspects of water. To promote children's understanding of water and its different dimensions, we should aim for a more systemic and multidimensional discussion of water in the context of our life. This approach means integrating scientific, environmental, societal and even technological questions into instruction.

Previous studies concerning science learning often focus on examining some particular viewpoints of water issues and separating the physics, chemistry and environmental aspects from each other: sinking and floating (Kawasaki & Herrenkohl, 2004; Havu-Nuutinen, 2005), evaporation, boiling, and condensation (Tytler, 2000; Varelas, Pappas and Rife, 2006), the water cycle (Ben-zvi-Assarf & Orion, 2005; Márquez, Izquierdo, & Espinet, 2006), or more broadly, the watershed (Shepardson, Harbor, & Wee, 2005; Patterson & Harbor, 2005; Shepardson, Wee, Priddy, Schellenberger & Harbor, 2007). These studies have revealed that at different ages, people possess an incomplete picture of the phenomena of water and the water cycle, including many preconceptions and misconceptions about it. For example, pupils did not connect the watershed concept to their everyday life sphere in which they live, play, and go to school. In addition, pupils' conceptions about watersheds largely focused on natural landscapes rather than the urban or human managed landscapes in which most of them live. In previous studies, pupils did not understand that water transported across the land and through surface water, distributes the effects of human activities throughout the watershed. In essence, pupils did not display an understanding of the human being as a part of the watershed or of concepts that would lead to an understanding of how human activity has an impact on the watershed and the quality of water. (Shepardson et al., 2007.) As pupils' views of water issues are contextually based and studies have considered water issues from a particular perspective, it seems that we need more information which would link several water issues together. When considering water in different contexts, it offers opportunities for children to conceptualise and link the different aspects of the phenomena.

It is difficult to understand water as a system in which several sub-systems are interrelated. Pupils do not understand scientific conceptions about parts of systems which are hidden from everyday view, such as water in aquifers, water in water treatment systems, or water vapour in the atmosphere. Even when pupils recognise how water exists underground, connections to other systems such as surface water systems or human-engineered systems, remain unclear to many. The incomplete understanding of water as systemic process makes it difficult for pupils to trace and conserve water entering or exiting connected water systems (Covitt et al., 2009).

### *Learning Water in School Science*

The Finnish national core curriculum (National Board of Education, 2004) stipulates that school science learning should be approached from a multidimensional viewpoint, strengthening the several aspects of the phenomena in a context of the pupils' life. The curriculum also guides teachers to consider the learning task as an integrated subject which shows the links between the theoretical aspects and everyday life. In the core curriculum, water as a substance is included in several core content:

- 1) Organisms and living environments (the basic features of living and lifeless nature, various living environments and the adaptation of organisms to them, nature through the seasons, the most common species of plants and animals in the pupils' immediate environment).
- 2) Substances around us (properties and changes in the state of water; the utilisation of water; the water cycle in nature).

- 3) The human and health (daily health routines, caring for one's own health, the importance of family, friendship, interaction and the recognition of feelings associated with well-being and mental health).
- 4) The home region and one's immediate environment, the world as an environment for human habitation (the immediate environment, seasonal change, home and provincial regions; natural conditions, landscapes, constructed environment, and human activity).

The National core curriculum does not provide any methodological support to integrate ideas the presented, and thus instruction often remains on a level that does not support the intended targets. Experimental and integrated school learning is recommended in the curricular text, but in reality, teaching is often conducted using textbooks (see Heinonen, 2005; Perkkilä & Lehtelä, 2007). In our experience, we have found it beneficial to guide pupils towards perceiving water from varying viewpoints, taking into account environmental and scientific issues. At the same time, we have tried to support the pupils so that they form an understanding in which water issues are considered widely, connecting both natural and human-engineered systems.

This study stemmed from the aim of considering how pupils see water multidimensionally, from the societal, scientific, environmental and technological aspects. If at school, science issues are handled as a part of societal and environmental questions, not separating them from everyday life, studying may strongly support pupils' critical thinking in their collective work for the future (Aikenhead, 1994). In supporting the development of pupils' critical thinking, there is a need for systemic experiences together with several process skills. For example through comparing and evaluating different dimensions of the phenomena, pupils learn to become critical (see also Havu-Nuutinen & Ahtee, 2007). With this in mind, the STS studying approach has been applied for the whole of this research and has been used as a framework in carrying out the instruction. The STS studying approach focuses on scientific issues, as well as on the societal and technological aspects of a phenomenon. Thus, the social environment for using water, is integrated within the scientific and technological questions relating to water. According to the STS approach, scientific phenomena are considered multidimensionally in teaching and studying, particularity from the viewpoint of societal life and social decision making. The STS teaching and learning process raises questions which lead pupils to think of and discuss issues which are meaningful to them in societal, technological and scientific life spheres. In many cases, traditional science curricula have focused on issues that are not significant for future citizens or members in society (see Aikenhead, 2005). If we systematically concentrate on questions related to current issues in society, we could educate pupils to be more critical and better-informed in the future.

According to Tytler (2000), the conceptual change process should be based on pupils' previous, everyday experiences. Important aspects of teaching and learning are to model and test ideas in the light of everyday experiences as well as identify a series of contexts which relate to the concepts being taught. Perceptions are often details which are based on everyday experiences, sometimes without scientifically linked reasons. Pupils' perceptions should be analysed within the contexts in which they describe them. Perceptions describe the initial and disconnected thoughts on the phenomena rather than conceptions, which focus more on explanations, attitudes and knowledge (see White, 1988). Support is therefore needed to help pupils consider how they perceive the phenomenon in different contexts. Based on these perceptions, conceptions can be formulated and argued without the particular learning context. In this study it is referred to perceptions instead of conceptions, because conceptions reveal broader understanding than received in this paper. This research is approached through issues, which take into account the combination of societal, scientific and technological viewpoints; pupils' perceptions of water issues are examined through a more interactive and global view of science learning.

## Research Questions

The aim of this study is to describe the context of STS instruction phenomena which pupils associate with water. In contrast to earlier research, we aim to consider water issues from several viewpoints, in an authentic school context. We are interested in pupils' perceptions of water issues before and after studying them. The STS approach is used as a framework for the teaching and learning processes. Our research focus on questions:

- What are the pupils' perceptions of water before and after the teaching and learning process?
- How do pupils' perceptions change during the teaching and learning process?

## Method

In an authentic school context, this research examined a teaching and learning process in which pupils' perceptions of water issues were analysed. A control group was not used because we did not aim to compare, but to describe and understand the strengths and weaknesses of the STS approach in studying water issues. The research followed a case study design (Gomm, Hammersley & Foster, 2000). This study involved a rural primary school in eastern part of Finland fourth and fifth graders aged between 10 and 11. Two fifth grades and one fourth grade classes participated in the study, totally 67 pupils, but only for 52 pupils' pre and post data exist and they were analysed. According to the curricula, the learning goals of both grades were very similar. Where both groups are reported, each grade has been mentioned specifically. The water issues included in the research belong to the curriculum and yearly schedule of the school, thus following their normal daily routines. The study was carried out in March-April, year 2008.

### *Essays and Drawings as a Method of Data Collection*

Before the studying process, pupils were asked to write an essay about the issues that came to mind when they thought about water. If needed, the pupils had an opportunity to ask further questions to help them in the writing process. In addition, they were asked to draw about water. The class teachers instructed the pupils to draw "water around us". The pupils had one hour (60 minutes) to write their essays and another hour for drawings. The tasks were carried out on separate days.

These data collection methods are used for a specific purpose, namely for capturing the pupils' perceptions of water, to achieve as complete and diversified a picture of the perceptions as possible. The essays play a primary role because the pupils wrote essays twice, but made only one drawing.

Writing essays are a productive way for learning science (Robertson, 2004) and there have been several accounts which confirm this (Ellis, Taylor, & Drury, 2005). The essays enabled us to capture the pupils' own style of writing, gathering data which had been personally produced by the pupils, using the concepts familiar to them. Essays reveal pupils' perceptions through their own individual ways of describing and interpreting issues (Ellis et al., 2005). The researcher is not able to influence the descriptions as might be the case in interview situations. In addition, essay writing supports relevant interpretation as the scientific phenomena is related to some particular context, which makes descriptions more concrete and content based. Compared to individual interviews, writing essays are also a productive and effective way of collecting data. However, that depends on the pupils' abilities to describe their perceptions. If pupils do not know

proper words or terms to describe their perceptions and experiences, they cannot produce valid essays or they might be misunderstood (see Robertson, 2004).

There is plenty of evidence that pupils' drawings can be a useful tool both for probing their level of understanding of natural phenomena and for identifying the pupils' scientific view (see e.g. Dove et al., 1999). For data collection, they offer an alternative to oral and written methods. Drawings can be a tool for visually perceiving one's own conceptions. They may help pupils to clarify conceptions of particular science phenomena and thus help them to achieve a higher level of thinking such as making links between concepts (Brooks, 2009), as well as presenting information that sometimes cannot be written or spoken. However, as the only method for capturing pupils' perceptions, drawings are not supported. Using them to elicit understanding may have its limitations, since what the pupils produce is partly dependent on their drawing ability: even though children may understand a concept, it does not mean that they can draw it accurately (Dove et al., 1999.) According to Ehrlén (2009), pupils' drawings are contextualised descriptions and thus cannot reveal overall understanding of an individual subject. The contextual factors and pupils' drawing abilities affect the mode of drawings they produce, similar pictures may represent different conceptions. (See Ehrlén, 2009.) With this in mind, combining drawings with some other methods allows more ideas to be presented. In previous studies, children's ideas about abstract concepts have been explored through drawing activities, in conjunction with interviews (e.g. Ben-Zvi Assaraf & Orion, 2005; Ehrlén, 2009). In this study, both drawings and essays are analysed to complete the validity of the research and to provide the pupils with different ways of representing their perceptions of water.

#### *Teaching and Learning Processes and Aims*

After the pre-phase of writing essays and producing drawings, pupils participated in instruction given by Master level student teachers of science and technology education who had specific competence concerning these issues. Nine student teachers supervised the first group of fifth graders (case 1, n=26), four student teachers supervised the second group of fifth graders (case 2, n=25) and four student teachers supervised the fourth graders (case 3, n=16). Student teachers planned the lessons together, but only a pair or a small group of students taught the class at one time. All the classes had four lessons, each lasting 90 minutes. The first had one extra lesson concerning air. During instruction, pupils considered water in its different forms such as the water cycle, pollution, water purification and the states of water (see more detailed Keinonen et al., 2008; Table 1, Table 2). Pupils made short experiments and performed inquiry-based activities, in which water phenomena were observed in a concrete way.

The general pedagogical aim of the lessons was to encounter the pupils' abilities to share their knowledge and discuss their perceptions and experiences of water. The observations were first discussed collaboratively (see Dillenbourg, 1999) and at the end of the studying sessions, together with the teacher. Thus, the conceptualisation of the phenomena was confirmed by the teacher. The learning results were individually documented in separate water project workbooks. Thus, the socially shared knowledge construction process was used to support the individual process of conceptual change.

The challenges of the study relate to the social and physical aspects of the learning environments. During instruction, both the class teacher and the student teachers were present in the classroom; the pupils were not used to so many adults at the same time. This caused some confusion when support was needed and to some extent, prevented full concentration. In addition, the pupils were not used to working in collaboration and making inquiries. The learning method was new to them; hence the pupils lacked routines for working.

Table 1. The content of teaching sequences and aims of the 5<sup>th</sup> grade lessons (a. Case 1, and b. Case 2)

Lesson	Content of the lesson	Aims of the lesson
<b>1st unit</b>		
a) Societal issues concerning water	a) Pupils read and discussed an article published in the local newspaper. Each pupil filled in an exercise sheet concerning the water cycle in nature. The pupils considered where water is used and the problems concerning it.	a) To understand water as a part of society and its significant role in human life.
b) Water supply in the town	b) In small collaborative groups, pupils searched for information concerning the local water supply. They used the brochure of the local water company, and marked on the map places where the water is taken and the areas of ground water.	b) To understand the local water supply and water as a part of society.
<b>2<sup>nd</sup> unit</b>		
a) States of water	a) Pupils made experiments in groups: surface tension, evaporation, melting, water as being solvent, and the pressure of water. Each pupil filled in inquiry cards while working. The states of water were learned through group activities in which they had different states of water and scientific explanations.	a) To learn to observe the process of water states and to observe different aspects concerning water.
b) Water purification in society	b) Pupils visited the water purification plant. They listened to the presentation and asked questions.	b) To understand the basics of mechanical, biological and chemical water purification.
<b>3<sup>rd</sup> unit</b>		
a) The local water supply and treatment process	a) Pupils visited the local water company, observed and listened to the expert's presentation. Finally, they filled in an exercise sheet.	a) To gain knowledge about the sources of water. To see technological systems of water purification.
b) Water cycle, water in the world	b) Demonstrating the formation of ground water in small groups. Pupils filled in an exercise sheet which included a picture of the water cycle. They read an article on different water situations and then discussed it.	b) To understand the water cycle, and water resources in the world.
<b>4<sup>th</sup> unit</b>		
a) Water supply in the local area.	a) Discussion about the water supply and its purification in the town. Explaining the previous observations summarising the water purification methods with transparencies.	a) To understand what the water supply and its purification means.
b) Properties of water	b) Properties of water: surface tension, osmosis, capillary phenomenon, color chromatography, water as being solvent. Pupils worked at activity stations in small	b) To understand the properties of water.

Table 2. The content of teaching sequences and aims of the 4<sup>th</sup> grade lessons

Lesson	Content of the lesson	Aims of the lesson
<b>1st unit</b> Society and technology in issues concerning the weather	Pupils watched a slideshow about water in different places and held small group discussions about the influence of the water in the picture. The following themes were discussed: meteorologists, weather maps, forecasting and the phenomena behind it. Pupils also designed equipment for weather forecasting.	Orientation towards the issue of water, its role in the world and the fact that all water is not visible to us. To understand what constitutes the phenomena of weather, how to make forecasts and the symbols used in them.
<b>2<sup>nd</sup> unit</b> The water cycle and states of water	Based on their homework, pupils drew a diagram of temperature. The demonstration about boiling water. The meaning of the water cycle was clarified by searching for information on the internet and working in pairs at activity stations.	To understand the states of water and the water cycle.
<b>3<sup>rd</sup> unit</b> Water cycle in nature	Based on the homework, a histogram was drawn on water consumption and there was discussion about how to save water. Pupils made experiments on the following themes: rain, surface tension, temperature, ground water.	To learn to save water, to make experiments, to understand properties and also the water cycle.
<b>4<sup>th</sup> unit</b> Problems concerning water	Pupils read articles about the problems concerning water: flood, drought, pollution; they worked in collaborative groups each with its own problem, discussing reasons and societal influences. Concluding the water issue with a mind map.	To learn to understand the societal problems related to the water and to work co-operatively assessing one's own learning.

When the four week instruction period was over, the pupils were again asked to write essays about what came to mind when they thought of water. The post-writing was carried out during the week after the teaching and learning process. 52 out of 67 pupils participated in both the pre-writing and post-writing phases. Some pupils were absent on the writing days, some on the pre-writing days and others on the post-writing days.

#### *Data Analysis*

Content analysis (see Roth, 2005) was chosen to analyse pupils' descriptions in order to find out the themes and details that pupils connect to water and the variance in their answers. First, details from the drawings and essays were collected. The authors looked at the drawing and read the writing material individually, in order to collect all the different information from the data. The

authors constructed the primary coding schemes which were based on the individually analysed data. In the second phase, the coding schemes were compared and discussed together by authors in order to verify the analysis process and to agree on descriptions, exact concepts and meanings. Finally, the coding schemes were combined in the cases in which the content description was similar. The additional coding schemes were maintained and taken into account in the following analysis phase. The orientation for the analysis was inductive, but in the final phase, the cases were reviewed based on the STS categories: science, society and technology. The frequencies of each category were counted and a quantitative comparison was produced. Further, the data in the STS categories was qualitatively analysed aiming to describe the particular characteristic of these categories. Analysis showed that the main categories from the essays and drawings were life related aspects; environmental interconnections with water, the physical and chemical properties of water and the technology related to it. These themes are discussed in more detail in the following chapter.

## Results

Prior to the teaching and learning process, pupils mostly associated the role of water and its importance for human beings and everyday activities, with drinking and washing (see Table 3). Fourth graders, in particular, considered water as a source of life and its meaning for living things in general. This viewpoint occurred less in the post-writing essays, but water was still seen as a living environment for plants and animals in general. Many pupils mentioned the proportion of water in the human body. The fifth graders built up the link to life by describing lots of biotic elements and their need for water. The relation between water, plants and animals, was described widely and with specified knowledge. Abiotic elements were not mentioned by fourth graders before studying, but in many of the post-writing essays, water was linked to clouds and the sun. Already prior to the teaching and learning process, fifth graders included abiotic elements such as the sky, clouds and rain, in their descriptions of water, but these issues were not mentioned in association with the water cycle. Water circulation was described in many papers after participation in instruction.

Most often, water was mentioned in essays and drawings in the context of everyday activities. Before and after teaching, pupils of both grades described water using recreational terms such as swimming and fishing. In almost every paper, water was linked to swimming in a lake, in the sea or in a swimming pool. Some other daily activities mentioned were drinking, eating and cleaning. The role of water was seen as being significant to the pupils' own life activities and so they wrote about it from their own viewpoint. After instruction, in the essays of both grades, there were less descriptions of water in everyday activities.

Prior to the teaching and learning process

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

After the teaching and learning process

“ I can wash myself with water and water can be used for washing furniture. You can dive, swim or fish”.(boy 26, 5<sup>th</sup> grade)

“Water is wasted a lot each day. I only use a little of it.” (girl 19, 5<sup>th</sup> grade)

Table 3. Frequencies of pupils' descriptions about water in essays and drawings before and after studying

Category	Essays		Essays		Drawings		Totals
	4 <sup>th</sup> graders prior to studying	4 <sup>th</sup> graders after studying	5 <sup>th</sup> graders prior to studying	5 <sup>th</sup> graders after studying	4 <sup>th</sup> graders prior to studying	5 <sup>th</sup> graders prior to studying	
Daily activities	46	40	41	16	3	65	211
Biotic elements	18	15	25	10	24	46	138
Abiotic elements	0	12	14	15	24	72	137
Geographical descriptions	26	12	12	11	10	42	113
States of water	20	26	11	25	2	17	101
Environmental descriptions	9	14	9	10	5	-	47
Human being	13	4	2	4	4	19	42
Human-engineered systems	-	-	-	-	7	20	27
Descriptive characteristics of water	1	4	16	5	-	-	26
Life in general	12	3	3	6	-	-	24
Chemical symbols of water	5	5	8	4	-	1	23
Totals	143	131	141	106	79	292	889

Recreation in the summer time, for example swimming, fishing, boating and water-skiing, were typical features in both the fourth and fifth graders' drawings (Figure 1). There were only a few drawings concerning sports in the winter time, for example skating (Figure 2).

Beside the everyday use of water, pupils focused on the biological relations of water. Biotic and abiotic elements such as human beings', plants' and animals' needs related to water, were systematically taken into account in the essays and drawings. Pupils wrote about the role of water as being one of the significant elements of life and its sectors.

Prior to the teaching and learning process

"People and animals need water a lot. [...] Water is needed that people and animals can live." (girl 13 4<sup>th</sup> grade)

"Fish live in water, also some mammals. Without water, human beings will die in a couple of days." (boy 7, 4<sup>th</sup> grade)



Figure 1. The drawing reflects a perception of recreation in the summer time and the use of water in everyday activities. (girl 31, 5<sup>th</sup> grade)



Figure 2. The drawing depicts recreation in the winter time.(girl 32, 5<sup>th</sup> grade)

In terms of biotic elements, there were no significant changes in the pupils' perceptions of abiotic and biotic relations of water. However, after the teaching and learning process, the issues were expressed on a more general level.

After the teaching and learning process

“Without water we do not have plants or life on earth. Human beings need water every day.” (girl 19, 5<sup>th</sup> grade)

“Water is an important liquid for human beings, plants and animals. [...] Water is important for all life.” (girl 17, 4<sup>th</sup> grade)

Pupils included components of the biosphere such as humans, animals and plants in their drawings of water. Fifth graders in particular drew human figures and the interaction between humans and water, such as water consumption and water in their everyday activities (Figure 3). The drawings mainly concerned freshwater ecosystems. Figure 4 typically represents drawings in which pupils presented both the abiotic and biotic elements together. The main abiotic elements were water, stone, sand, the sun and the sky, while the biotic elements were plants and animals, especially fish or mammals.

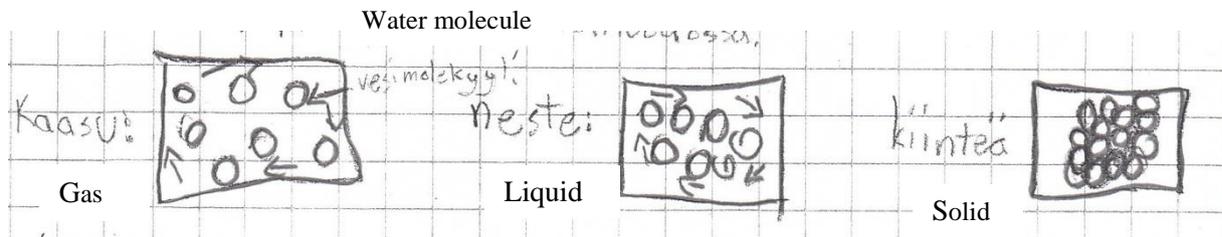
Even though prior to teaching, snow and ice were recognised as a form of water, instruction guided them to consider the states of water more comprehensively. Some pupils described the molecular model, how the behaviour of molecules changes in different states. In addition, the 5<sup>th</sup> graders linked the states of water to the seasons and water circulation in nature.

Prior to the teaching and learning process

” If water does not exist, there would be no snow either, all plants would die away and there would not be any water for drinking. (boy 9 4<sup>th</sup> grade)

After the teaching and learning process

“ water can be in many states:



(boy 8, 4<sup>th</sup> grade )



Figure 3. The drawing depicts water consumption. (girl 6, 5<sup>th</sup> grade)



Figure 4. The drawing presents the abiotic and biotic elements of the fresh water ecosystem. (girl 6, 4<sup>th</sup> grade)

Pupils in the fifth grade drew snow and ice as a form of water in nature. Some lakes or ponds had an ice cap and a few pupils drew ice sheets and an ice cube. An interesting societal aspect was the description of water as a part of environmental protection. Pupils did not systematically write about the environmental aspects prior to studying, but afterwards, these descriptions clearly increased, especially among the fourth graders. In addition, pollution was an issue which was mentioned by the fourth graders prior to the teaching and learning process, but afterwards, no increase was noticeable. The drawings depicted features of the water ecosystem such as water pollution, toxic and poisonous water (Figure 5), and the source of the water pollutants was shown in the form of sewage and contamination by radioactive substances. Pupils also drew human-engineered systems, e.g. water purification and water distribution at a local level (Figure 6).

Prior to teaching and learning, 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. They also described which forms of water can be found on the earth and how the sea and a river differ from each other. However, the water run-off to the sea was not described. After the teach-

ing and learning process, these details were connected to each other, implying more causal links and interconnections between the phenomena.

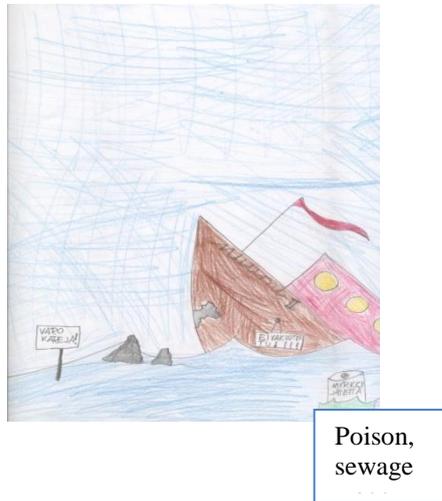


Figure 5. The drawing reflects the source of pollutants in water.(boy 7, 4<sup>th</sup> grade)

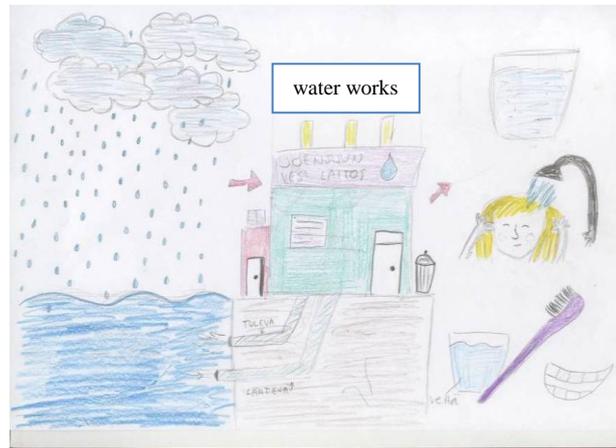


Figure 6. The drawing represents the local water purification system.(girl 19, 5<sup>th</sup> grade)

Prior to the teaching and learning process

“The earth is the only planet where water exist. [...]Water can be found from lakes, rivers, seas, streams and ponds. The earth is covered mainly by water”. (boy 7, 4<sup>th</sup> grade)

After the teaching and learning process

“Water is a liquid which you can find from nature: lakes, rivers, seas and ponds. In some countries they do not have enough water and people die of thirst. In some places there is flooding because after drought, the land cannot absorb the water.[..]”(boy 7, 4<sup>th</sup> grade)

There were few references to habitation in the drawings. Most of them depicted natural areas versus developed areas and none of the drawings or essays contained references to agriculture or industry at a waterside location. However, human beings, plants and animals in, around and on the banks of lakes and fresh water on the earth surface, were frequently mentioned. Only one drawing highlighted the fact that fresh water resources are only a very small part of global water resources, compared with the water in the seas. Pupils only showed that e.g. lakes receive their water input from streams or from the transpiration of water between a pond/lake and a connecting creek (see Figure 7). Some drawings indicated pupils’ understanding of how water moves through environmental systems and interacts with other substances such as air and soil (see Figure 8).

Prior to the teaching and learning process, water as a substance was discussed through everyday descriptions of water characteristics. In the fifth graders’ essays, they had described water in relation to its colour and odour. Some pupils mentioned the chemical symbol of water both before and after the teaching and learning process, but there was no increases its use during the process and the chemical symbol of water was seen only in one drawing.

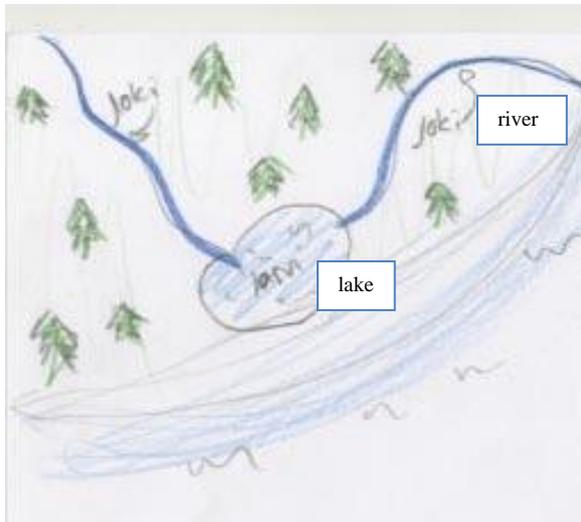


Figure 7. The drawing represents the connecting lake and river. (boy 3, 4<sup>th</sup> grade)



Figure 8. The drawing reflects a perception of water movement through environmental systems. (boy 11, 5<sup>th</sup> grade)

After the studying process, pupils wrote about the meaning of water in science, technology and society. Despite STS instruction, the codes in the pupils' answers fell into the same categories as previously, but the content varied somewhat. Pupils' essays were more compact than before, but the content was more comprehensive. The essays were written at a more general level, examining water as a substance and although pupils did not describe the aspects of using water in detail, they considered the phenomenon of water in nature more broadly.

Although prior to instruction, the fourth graders had lots of fragmented ideas about the problems related to water and the states of water, they did not express them at all after instruction. It was water circulation and purification that came more to the fore. They perceived water in a more systemically and described it in a broader context. Generally, the fourth graders' wrote more comprehensively about the different kind of perceptions, although they wrote less about societal issues than before instruction.

Prior to instruction, the fifth graders' essays included more descriptions of purification and the lack of water; they also described the use of water, water related problems, the states of water and the uneven distribution of water in the world. Afterwards, they only considered the lack of water. After instruction, almost all fifth graders, especially the girls, wrote about the factors which were discussed during the teaching and learning process, also describing more societal issues such as the history of water, its meaning for life and for human beings.

## Conclusion and Implications

This study has given an overview of fourth and fifth grade pupils' perceptions of water that occurred during the STS teaching and learning process and showed how perceptions of the water system changed. The aim of the research was to gain more knowledge about how pupils perceive water, based on essays and drawings used in the STS teaching and learning process. Previous

studies (Varelas et al., 2006) have shown that pupils theorise aspects of the same phenomena in different ways and that their conceptions are contextually based. In addition, many studies have demonstrated that a connected understanding of water related systems is difficult to achieve (see Varelas et al., 2006; Covitt et al., 2009). The STS approach connects and integrates the science content with the pupils' everyday sphere in a manner that reflects the pupils' natural efforts to make sense of it all (Aikenhead, 1994). According to this study, prior to teaching and learning, the fifth graders' perceptions were very fragmented and atomistic. They described lots of details from everyday life which concerned water. Recreation was frequently connected to water, as was also cleaning. Water as an everyday tool seems to be familiar to the fourth and fifth graders, but their perception of the water cycle did not become apparent before writing about it in the post-phase essays (see also Ben-Zvi-Assarf & Orion, 2005). Pupils' descriptions in these post-phase essays focused more on the states of water and the water cycle. After teaching and learning, the pupils described the connection between the water resources and the role of water for life and considered water from natural and geographical points of view. Although the descriptions were more compact and limited than before, the descriptions were more systemic and included several causal relational aspects in which fragmented perceptions were combined. This emphasises the idea of causality and construction process toward conceptions, which is an important aspect of school science education and highlighted in some previous studies of water phenomena (Shepardson et al., 2007; Covitt et al. 2009). Although in this research, we did not aim to report pupils' conceptual change processes, school teaching should help pupils to link their fragmented perceptions, in order to support changes in pupils' perceptions and conceptions in terms of ontological aspect of scientific issues. (see Havu-Nuutinen, 2005.) However, the challenge of this study was to find the link between the existing perceptions and the new, studied ones. The approach used, helps pupils to recognise the entities and sub-processes of water in order to be able to link them to each other. As this approach was not systematically accomplished by the student teachers, the aim was not fully achieved. Even though pupils considered the water system more comprehensively after the teaching and learning process, many of the details previously mentioned in their essays were later omitted. This indicated that in every case, the link between previous perceptions and learned issues had not been fulfilled. The pupils seemed to ignore their existing knowledge prior to instruction, and brought to the fore those aspects they had learned during the process. For example, states of water were mentioned systematically after teaching and learning and it seemed to be a new aspect for the pupils. Very similar findings are reported by Österlind and Halldén (2007) 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.

Understanding the concept of water was not the only matter under instruction, the technological and societal issues were important as well. Hence, the pupils initially considered what things, such as recreation, are related to water and are important to life. Later, their understanding of the interrelations (cycles, states, and environmental problems) seemed to develop. It seemed that the STS approach supported at least some pupils' abilities to see water in a wider perspective than previously. However, even if the instruction was well planned, the learning project was too short for changing the conceptual orientation of all pupils. More experiences would be needed for profound understanding of water phenomena. It seems that pupils would need more conceptual support for constructing a comprehensive, theoretical understanding of water phenomena and being able to express their perceptions through writing. Thus, science projects at school should last several weeks in order to allow enough time for fundamental thought on the part of the pu-

pils, and to ensure that the teachers' role as a link between empirical observation and theoretical systemic thinking has been effective.

This experimental research focused on one of the main phenomena of life. Water as a subject has a meaningful role in terms of environmental education, but also a wider understanding of scientific phenomena is strongly linked to the understanding of water. The pupils' writings and drawings revealed viewpoints which varied from scientific, describing water as a substance, to those concerning environmental protection. Environmental aspects of water such as pollution and water protection, occurred mainly after teaching and learning. The fourth graders in particular, wrote about environmental issues after the teaching and learning process, which might be caused by the content of the last study session (see table 1). The environmental aspects seemed to become clearer for pupils who read articles about those specific issues.

This study supports the use of society-oriented approaches in which the multidimensional and cross-scientific view of the phenomena is the goal of the instruction. This is because a fundamental understanding of water as an environmental system is essential in helping young people make their future decisions concerning natural resources. The essays were more complete after the teaching and learning process and pupils considered water cross-scientifically, finding links between the knowledge areas. To this extent the STS approach seems to fulfill the aims of the core curriculum.

This study has been carried out in an authentic school context as part of normal school work, with the exception of student teachers being unfamiliar to the pupils. The structure of this research partly follows the design of a process study, in which a certain process is followed from the beginning to the end capturing the changes in the pupils' perceptions. The study cannot produce results which are controlled by particular variables, but this study does bring to debate on science education, an awareness of concrete pedagogical challenges. In addition, based on the carefully described teaching and learning process, we are able to find links between teaching and learning outcomes and evaluate the quality of the changes in pupils' perceptions. To some extent, the study results are limited from the viewpoint of controlled study design, but on the other hand, this study has been conducted using methods that can be transferred to any school setting.

There has been some discussion about the relevance of drawings and essays as a valid data collection method for gaining knowledge about pupils' perceptions and understanding of scientific phenomena. Because, ground water, for example, may be difficult to draw, that is possibly the reason for leaving it out of the drawings. On the other hand, the pupils studied the water supply system, and could draw e.g. buildings and pumps when they wanted to describe groundwater pumping. Pupils wrote about the water supply in their essays, but there were few written descriptions of the ground water. This suggests that there may be details that the pupils could not draw but could literary describe. Conversely, some things such as clouds with rain may be easier to draw, hence these perceptions may be expressed more easily by drawing than by writing (see also Dove et al. 1999). We noticed that both methods are valuable as sources of information about pupils' perceptions. To some extent, drawings and writings produced different information; however the perceptions found in both data were coherent, focusing on very similar water issues. In our data analyses we could identify relevant common categories in both sources of information.

Ehrlén (2009) has recently stated that children's drawings can be used to grasp their conceptions only by considering the meaning the children themselves give to their own drawings. We agree with Ehrlén in that there is a certain danger in interpreting drawings, but because the data was achieved by using two methods, the interpretation of drawings was confirmed with essays in cases which were unclear. In addition, the authors carefully discussed, compared and analysed the data material together to achieve valid analysis. This research has shown that, even though it may be different from that of the essays drawings can also give relevant information. Our interest

was not in the more general conceptions, but in all perceptions that pupils have. In our case it was more important to find out what aspects the pupils connect to water and in which context they describe it, rather than examining how deeply they understand water. Through comprehensive and multidimensional interpretations of pupils' perceptions, educators are able to support pupils' integrative teaching and learning processes in environmental and science phenomena.

## References

- Aikenhead, G. (1994). What is STS Science Teaching? In Solomon, J. and Aikenhead, G.S. (Eds.) *STS Education*. New York: Teachers College Press, 47–59.
- Aikenhead, G. (2005). Research into STS science education. *Education Quimica*, 16, 384–397.
- Ben-Zvi-Assarf, O. and Orion, N. (2005). A study of junior high students' perceptions of the water cycle. *Journal of Geoscience Education*, 53(4), 366–373.
- Brooks, M. (2009). Drawing, visualisation and young children's exploration of "big ideas". *International Journal of Science Education*, 31(3), 319–341.
- Covitt, B.A., Gunckel, K. L. and Anderson C.W. (2009). Students' developing understanding of water in environmental systems. *The Journal of Environmental Education*, 40(3), 37–51.
- Dillenbourg, P. (Ed.) (1999). Collaborative learning. cognitive and computational approaches. advances in learning and instruction series. Amsterdam: Earli:Pergamon.
- Dove, J. E., Everett, L.A., & Preece, P.F.W. (1999). Exploring hydrological concept through children's drawings. *International Journal of Science Education*, 21(5), 485–497.
- Ehrlén, K. (2009). Drawings as representations of children's conceptions. *International Journal of Science Education*, 31(1), 41–57.
- Ellis, R.A., Taylor, C.E. and Drury, H. (2005). Evaluating writing instruction through an investigation of students' experiences of learning through writing. *Instructional Science*, 33, 49–71.
- Gomm, R., Hammersley, M. and Foster, P. (2000). *Case Study Method*. London: Sage Publishers.
- Havu-Nuutinen, S. (2005). Examining young children's conceptual change process in floating and sinking from a social constructivist perspective. *International Journal of Science Education*, 27 (3), 259–279.
- Havu-Nuutinen, S., & Ahtee, M. (2007). Teaching and learning science in primary school. In E. Pehkonen, M. Ahtee and J. Lavonen (Eds.) *How Finns Learn Mathematics and Science*. Rotterdam: Sense Publishers, 229–242.
- Heinonen, J-P. (2005). Opetussuunnitelmat vai oppimateriaalit: peruskoulunopettajien käsityksiä opetussuunnitelmien ja oppimateriaalien merkityksestä opetuksessa. [Curricula or educational materials] Researches 257. Faculty of Behavioural Sciences. University of Helsinki: Helsinki.
- Kawasaki, K., & Herrenkohl, L.R. (2004). Theory building and modeling in a sinking and floating unit: a case study of third and fourth grade students' developing epistemologies of science. *International Journal of Science Education*, 26 (11), 1299–1324.
- Keinonen, T., Ismail, P. and Havu-Nuutinen, S. (2008). Water: Fourth and fifth graders thoughts on it. *The International Journal of Learning*, 15, 247–254.
- Márquez, C., Izquierdo, M., & Espinet, M. (2006). Multimodal science teachers' discourse in modeling the water cycle. *Science Education*, 90, 202–226.
- National Board of Education (Eds.) (2004). *National Core Curriculum for Basic Education*. Helsinki: National Board of Education.

- Patterson, L.A., & Harbor, J. (2005). Using assessment to evaluate and improve inquiry-based geoenvironmental science activities: Case study of a middle school watershed e. coli investigation. *Journal of Geoscience Education*, 53(2), 204-214.
- Perkkilä, P. and Lehtelä, P-L. (2007). Learning environments in mathematics and science. In E. Pehkonen, M. Ahtee and J. Lavonen (Eds.) *How Finns Learn Mathematics and Science*. Rotterdam: Sense Publishers, 69–85.
- Robertson, I. (2004). Assessing the quality of undergraduate education students' writing about learning and teaching science. *International Journal of Science Education*, 26 (9), 1131–1149.
- Roth, W-M. (2005). *Doing Qualitative research. Praxis of methods*. Rotterdam: Sense Publishers.
- Shepardson, D.P., Harbor, J. and Wee, B. (2005). Water towers, pump houses, and mountain streams: Students' ideas about watersheds. *Journal of Geoscience Education*, 53 (4), 381-386.
- Shepardson, D.P., Wee, B., Priddy, M., Schellenberger, L. and Harbor, J. (2007). What is a watershed? Implications of student conceptions for environmental science education and the national science education standards. *Science Education*, 91(4), 554-578.
- Tytler, R. (2000). A Comparison of year 1 and year 6 students' conceptions of evaporation and condensation: dimensions of conceptual progression. *International Journal of Science Education*, 22(5), 447-467.
- Varelas, M., Pappas, C.C. and Rife, A. (2006). Exploring the role of intertextuality in concept construction: Urban second graders make sense of evaporation, boiling, and condensation. *Journal of Research in Science Teaching*, 43(7), 637-666.
- White, R. (1988). *Learning science*. Cambridge: Basil Blackwell.
- Österlind, K. & Halldén, O. (2007). Linking theory to practice: A case study of pupils course work on freshwater pollution. *International Research in Geographical and Environmental Education*, 16(1), 75–89.

## Authors

Sari Havu-Nuutinen, Adjunct professor, is Senior University Researcher on general Education focusing to early year's education and science education. Currently works as a teacher educator at UEF taking response of minor studies of pre-primary education. She gives lectures focusing on science education and educational psychology. Her research areas focus on young children teaching and learning in science education, especially knowledge construction and conceptual change in authentic learning processes. In addition, more current research deals with the issues such as quality of pre-school and children's and teachers' well-being in pre-school education and first and second grades. **Correspondence:** University of Eastern Finland, School of Applied Education Sciences and Teacher Education, P.O. Box 111 80101 Joensuu, Finland. E-mail: sari.havu-nuutinen@uef.fi

Sirpa Kärkkäinen is Senior Lecturer in Biology and Geography. She works with primary and secondary school teacher students and gives lectures focusing on science education especially biology, geography and environmental education. Her research areas focus on teacher education, for example inquiry based learning, collaborative learning and informal learning environments.

Tuula Keinonen is professor in research on general education especially science education. She holds PhDs in Physics and in Education. Her research covers students' perceptions of sciences,

teachers' growth and environmental education. She supervised PhD students and has experience in pre- and in-service teacher training. She has written science school books and coordinated several research projects.

### **BTT çalışma yaklaşımı bağlamında su kavramının ilköğretim öğrencileri tarafından algılanışları**

Bu çalışmada su konusunun çocuklar tarafından algılanışı üzerine yoğunlaşmıştır. Finlandiya ilköğretim okullarındaki öğretimsel durumlar üzerinde durulmuş ve Bilim-Teknoloji-Toplum (BTT) yaklaşımının tanıtmak amaçlanmıştır. Çalışmanın asıl amacı, çocukların su konularıyla ilişkilendirebilecekleri sorunları BTT bağlamında tanımlamaktır. Yaşları 10 ile 11 arasında değişen (n=52) kırsal alandaki bir ilköğretim okuluna devam eden 4 ve 5. sınıf öğrencileriyle çalışılmıştır. Öğretimden önce ve sonra su denildiğinde akıllarına gelen hususları yazmaları istenmiştir. Ayrıca, sürecinde başında öğrencilerden su ile ilgili çizimler yapmaları istenmiştir. Çocuklar, birinci grup yazım ve çizimlerden sonra, yüksek lisans düzeyindeki öğretmenlerin gözetiminde öğrenme ve öğretme sürecine katılmışlardır. Bu süreçten önce, yüzme ve balık tutma kadar içme ve yıkanma dikkate alındığında suyun insanlık açısından rolüyle ilişki kurmuşlardır. Çocukların algıyıları sınırlı olmasına rağmen bilimsel meselelerden çevre korumaya kadar çeşitli konular süreçte gündeme getirilmiştir. Öğretimden sonra, su döngüsü fikri de dahil olmak üzere, bilimden teknoloji ve sosyal meselelere kadar suyun ne anlama geldiğine yönelik çocuklar görüşlerini yazmışlardır. Bu çalışma, ottantik okul bağlamında su hakkında öğrencilerin fikir ve düşünceleri hakkındaki öğretmen ve araştırmacıların görüşlerini arttırmış ve bakış açıları genişletmiştir. Teknoloji konuları çevre ve bilim eğitimini zenginleştirmiştir. Çalışma entegre öğretim konusunda karşılaşılan sorunları ortaya çıkarmıştır. Yöntemsel anlamda bu çalışma, araştırma sonuçlarını yorumlarken çizim ve yazıların rolünü tartışmıştır.

Anahtar kelimeler: Su algısı, BTT öğretimi, çizimler, metinler yazma