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THE CHANGES IN PUPILS' CONCEPTIONS OF HUMAN BODY BASED ON SCIENCE, TECHNOLOGY AND SOCIETY BASED TEACHING

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Abstract. *This paper explores the changes in 12 year old pupils' conceptions of the organs and systems of the human body. The research was conducted as an intervention study in one Finnish primary school. The instruction was carried out by using the STS teaching approach which aims at linking the studying contents to everyday life contexts. The drawing method was used to catch pupils' conceptions of organs and parts of the body, before and after the teaching period. In addition, nine pupils were interviewed. Results indicate that before teaching, pupils were able to name several organs of the human body, but they had no understanding of how they function and what is their relation with each other. After the teaching period the pupils were able to name more of the organs and explain more clearly their function and meaning. In particular, the brain and digestive systems were understood more accurately.*

Key words: *human body research, conceptual change, Science, Technology Society -teaching.*

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Introduction

Previous research (for example Slaughter *et. al.,* 1999) has argued that the cluster of the main concepts of life, death and body function constitutes the basic structure of the first, vitalistic, intuitive biological theory. Those pupils, who have an understanding of life as a phenomenon of several processes, are in an appropriate cognitive position to develop new concepts that are commensurate with core biological theory (Venville, 2004). In terms of biological questions, the human body is an important learning subject area in the Finnish primary school. According to the national core curriculum (National Board of Education, 2004), in grade five, the main areas of learning in terms of the human body, are its structure and functions, reproduction and changes in the body during puberty. This study focuses on the processes of conceptual change and the influence of STS teaching (Aikenhead, 2000) intervention in the Finnish primary school.

A number of studies have clarified the pupils' understanding and conceptions of scientific concepts. These studies have generally shown that pupils' understanding of scientific concepts and processes varies and that some misconceptions are common. Previous studies which concern pupils' understanding of the human body (Reiss & Tunnicliffe, 2001; Reiss *et. al.,* 2002; Prokop & Fancovicova, 2006), show that pupils in various countries frequently have a wide knowledge of their internal body, and are capable of mentioning many separate organs. Gellert's study (1962), over 40 years ago, showed that pupils from 9 to 10 knew many separate organs, firstly the heart, lungs and brain (Carey, 1985; Osborne *et. al.,* 1992). However, pupils seem to have a poor understanding of how organs exist as related structures within the whole system (Gellert, 1962; Carey, 1985; Osborne *et. al.,* 1992; Reiss & Tunnicliffe 2001; Reiss *et. al.,* 2002). These misconceptions seems to be very stable, because majority of the science teacher

students have several misconceptions and inadequate knowledge in terms of heart internal structure (Bahar *et.al*., 2008).

Studies concerning the processes of the human body (see e.g. Teixeira, 2000; Carvalho *et. al.,* 2004; Venville *et. al.,* 2005) have, for example, referred to blood circulation, reproduction and digestion. These processes cause the pupils problems in describing them accurately. The digestive system is often linked to the stomach and the dissolving of food. It also seems to be the general conception that food is discharged or automatically disappears somewhere. The digestive process does not seem to be resolved (see Carey, 1985; Osborne *et. al.*, 1992). The majority of children aged 10 to 11, know that the heart pumps blood and it's needed to keep you alive (Osborne *et. al.*, 1992), but students' do not achieve complete understanding of heart structure eve at university level (see Bahar *et.al,* 2008). Òskarsdóttir (2006) has studied first and second grade pupils' conceptual development of the body and how their ideas change with the teaching environment. At the end of the project the pupils were generally more aware of the structure, location and function of several organs and also understood how they were related to one another. In addition, they became more aware of the body's different systems, especially the digestive systems (Òskarsdóttir, 2006.) In addition, there is indication that pupils' conceptions of the digestive systems gradually change between the ages of 4 to 10 (Carvalho *et. al.,* 2004). Based on these studies, it seems that pupils intuitively learn about some organs, but it should be school learning which strengthens the understanding of how the human body functions and teaching approach must support the conceptual development about biological systems. Evidence also suggests that the years at primary school are decisive in learning about the human body (see Reiss & Tunnicliffe, 2001).

Recent studies dealing with the questions of conceptual change (see Duit and Treagust, 2003) produce evidence that conceptual difficulties and misconceptions are a normal part of learning. Pupils attempt to construct meanings about the content of biology and other fields of science education. In contrast, the conceptual change approach in instructional settings is seen as an effective way of enhancing pupils' learning but it also increases the teachers' knowledge about pupils' cognitive skills and their experiences of the knowledge construction process within the learning context. Several studies have accessed an immense amount of information about the conceptual change process in pupils (see Havu, 2000, Carvalho *et. al.,* 2004), but more knowledge is needed about the processes in different contexts.

Generally, conceptual change research aims to clarify how pupils' conceptions change to become a scientific conception of a particular concept or phenomenon. The conceptual change process does not happen suddenly and processing can occur at several levels. (Havu, 2000.) Chi *et. al.* (1994) have considered conceptual change from the viewpoint of ontological and epistemological changes. This reveals the characteristics of pupils' understanding. When conceptual change occurs at the ontological level, it demands that the status of entity of pupils' conceptions move from one ontological level to another. Ontological changes demands strong changes in the pupils' conceptual structure and thus, young children especially are not able to reach ontological changes very quickly. Epistemological changes are not so radical and are linked to the way pupils process the knowledge. (see Chi *et. al.,* 1994; Havu-Nuutinen, 2005.)

This study focuses on fifth graders' (12 year old pupils) conceptual changes in conceptions. These relate to organs and functions of the skeletal system and muscles, brain, senses and nervous systems, digestive system, respiratory systems and blood-vascular system (see Keinonen, 2007). The pupils' conceptions are analyzed before and after a five-week STS teaching period.

Methodology of Research

General Characteristic of Research

This study belongs to the framework of STS teaching, which emphasizes *science, technology and society* aspects in learning, empowering the action of future citizens (Aikenhead, 2000). In STS teaching, science content is connected and integrated into the pupils' everyday life spheres, and in a manner that mirrors their natural efforts at making sense of it all. Science content does not stem from a vacuum. The STS approach, might be affecting variables in the science classroom that in turn affect achievement in

the sciences such as social negotiations (Tsai, 2002; Mbajiorgu & Ali, 2003.) Tsai (2002) has found that an STS oriented instruction group of students could perform better than a traditional group of students in terms of the extent, richness and connection of cognitive structure outcomes. He also states that due to its epistemological views being more oriented to constructivist views of science, STS teaching could be especially beneficial to learners particularly at the early stages (see also Keinonen, 2007).

Participants

Thirty, Finnish fifth graders, participated in this research during the autumn of 2006. The pupils came from one school, in the Eastern part of Finland. None of them had had formal instruction in anatomy of the human body (see National Board of Education 2004). At the onset of the study, all pupils filled in a picture, in which the contours of the body were drawn. Pupils were asked to fill in the picture with all the organs and parts of the body, they know. The drawings were categorized and analysed in terms of the quantity of the elements in their pictures. The amount of organs were counted and grouped into six categories (skeletal system, musculature, blood circulation, brain & senses, digestion and respiration). Based on the analysis, ten pupils were selected for the interview; five from the highest and five from the lowest scores. The learners were selected for the interview in order to clarify how pupils with the maximum or minimum amount of knowledge explain their understanding. Eventually nine pupils participated in the interview. The pupils were interviewed before being taught. During the interview, the drawings were used as a basis for the explanations and the questions concerning the names and functions of the organs.

Procedure

After the first part of data collection, a five week teaching period was conducted by teacher students and one researcher. The teaching modules were divided into the four themes of human biology: 1) skeletal system, joint and muscles 2) respiratory organs and function of the blood-vascular system 3) digestive system and nutrition 4) brains and nervous system 5) senses.

The studying themes were planned together with eight teacher students from a university course of science and technology education. The students who participated in the course studied at the master level of primary school teacher education.

Individual instructional sessions were once a week, over five weeks from October to November 2006. Each session lasted two hours every Thursday morning. The aims, the structure and STS connections of teaching period are described in table 1.

Table 1. The aims, materials and strategies of the school teaching.

Content	Aims of the session	Materials and strategies used	Link to STS teaching
Skeletal system, joint and muscles	to learn to recognize the most important bones to learn the structure of the bones to understand how important it is to care for the bones to understand the role of joints, the function of the muscles and how to care for them to understand the role of exercise, to learn to be in command of your own body and to find your own muscles to search for information independently to learn to interpret the figures to motivate pupils to increase their amount of exercise	paper (bones copied on a paper), X-ray, cd teachers´ drama discussion about the skeleton based on a story read by the teacher connecting a skeleton from the paper pieces (each pupils his/her own) exercises with music led by the teachers	good local facilities for physical exercise, opportunity in society for exercise and its significance, future orientation professions (physical exercise physical education instructors and teachers, physiotherapists, X ray assistants, dietician the pupils themselves recognise the problem

Content	Aims of the session	Materials and strategies used	Link to STS teaching
The respiratory organs and function of blood-vascular system	to learn to measure the pulse rate, respiratory frequency, volume of the lungs, blood pressure to learn to understand the respiratory system and the blood-vascular system to understand the dependence between the blood-vascular system and breathing to learn how to take care of the respiratory system	sphygmomanometer, respiratory meter, watch, paper experiments/inquiries in small groups or in pairs; filling in the inquiry forms and collecting the study and observation results; mind map on the table demonstration (transparency of the heart and its function)	technological devices used in the experiments the influence of physical exercise, nutrition, smoking and stress
Digestive system and nutrition	to understand the structure and the function of the digestive system to learn to know the parts of the digestive system and their function to understand the importance of energy for everyday life and especially exercise to understand the significance of healthy diet to learn modelling	T-shirt showing the digestive system, scissors, glue, balloons, elastic, thread, rope, plastics, paper, drinking straws, feathers, egg carton teaching discussion with demonstration (T-shirt) collecting a model of the digestive system in small groups answering the questions concerning the subject and a quiz	personal enthusiasm application of knowledge (modelling) the pupils learn to understand their own ideas about nutrition caring about nutrition
Brains and nervous system	to understand the structure and the function of brains and nervous system to understand the connection between nervous system and brains to encourage physical exercise, for a healthy and safe life to learn to experiment	materials play (demonstration of message progression with pupils) mind map on the table quizzical teaching experiments in small groups guided by the teachers	safety tools in cycling drugs everybody can influence his/her future
Senses	to know the senses and their significance to understand how people with sensory handicap compensate it to learn to search for information to learn to present information	books group work (searching for information from the book) member of each group presents the results in front of the class a quiz in pairs	technology related to different senses, discussions about the instruments

When the teaching period was completed, the pupils filled in a drawing similar to the previous one. The content of the interview was very similar to previous one, but also included some questions concerning their feelings about the lessons. Drawings were discussed in the interview and all interviews were audio taped.

Data analysis consists of the scoring and grouping of the organs present in the pupils' drawings. The organ was scored if it was drawn, named and located correctly in the body. The separate organs were categorized into the organ systems, based on the themes covered during instruction and the scoring systems used in previous studies (Reiss *et. al.*, 2002). In the results the percentage of organs named are presented and compared with the number before and after the teaching.

Interview data was analyzed using a content analysis method in order to discover the pupils' conceptions of organs; how the function of organs was explained and how holistically systems were described. Analysis focused on the meaning of organs and the functional system of organs. The results from before and after teaching were compared.

Results of Research

Before instruction the pupils were very knowledgeable about the separate organs of the human body. The pupils were able to mention several organs of the body, but the location and their purpose was unclear. The pupils had superficial understanding, which they could not specify in detail. In addition, the pupils described the function and meaning of the organs and organ systems at a very general level; all organs are necessary for living.

After studying the pupils' knowledge about the organs, their names and location became more clear and systematic in their drawings. The drawings revealed the pupils' level of understanding better than earlier, even though the organs were not drawn more exactly; they seemed to have more self-confidence than before the studying project. The pupils' awareness and abilities to describe the function and meaning of organs and organ systems clearly increased after teaching. In addition, the relationships between the organs in the human body were described in more detail.

Before the teaching period the skeletal system was often absent in the drawings. Only the bones of the arms and legs of the human body were present (Table 1). The pupils did not mention bones by names either before or after studying. Only one pupil drew the spine before studying but five pupils drew it afterwards. This is interesting, because the skeletal system is somehow a basic element of the human body

Table 2. The frequency of the inclusion of the organs of the skeletal system in the pupils' drawings prior to and after teaching.

Skeletal system	Before teaching	After teaching
Bones/bone	10	10
Rib/ribs	4	7
Spine	1	5
Skull	1	4
Knee cap	1	1
Breastbone		2
Hip bone		1
Thigh bone		1
Shoulder blade		1

Before teaching, some pupils systematically mentioned the spine and bones in the interviews, and though pupils were able to name some bones, their purpose was unclear. The bones were seen as separate parts of the body and their utility was unknown. The interrelations of bones couldn't be explained either. After the teaching period, bones were mentioned more systematically, although the pupils did not include them in their drawings. In addition, the role and purposeof the bones in the body became clearer.

Mark's knowledge and understanding changed during the studying project to become more detailed and intense. He was able to explain in detail about the function of the body and the role of the skeletal system in it (Table 3 and Table 4).

Table 3. Mark's interview before teaching.

Mark:	Here are some bones, and muscles
Intw:	Where do you have bones?
Mark:	Bones are everywhere in the body
Intw:	Okey.
Mark:	Here is the toe bone, and this is… oh I can not remember, it was radius, it is somehow there.
Intw:	In the arm, okey.
Mark:	And of course the spine, I don't know any more!
Intw:	What is the spine like?
Mark:	It keeps all the bones together.

Table 4. Marks' interview after teaching.

Intw:	What did you learn during the project?
Mark:	I learned more about bones
Intw:	To name them or?
Mark:	Not so much. I learned to know their shape.
Intw:	Okey, lets look at your drawing.
Mark:	Here is the shoulder blade, kneecap, leg or thigh bone, and here is the radius and of course the spine. And then I know some muscles.
Intw:	What is the role of bones?
Mark:	Bones keep the body built up and the muscles move them.
Mark:	Bones are separate ones, but there is a place, a socket, in which the bones are linked to each other.
Intw:	What is the name of the place?
Mark:	It is a joint, it is needed for moving!

Before studying on the project the bones were seen as being more separate from each other, but after studying, the skeletal system was understood more as bones interrelating with each other as well as being a skeletal system and muscles. The role of the muscles was seen to be to protect the human body.

In the drawings, like the skeletal system, the musculature was drawn at random. The pupils had drawn muscles somewhere just to show that there were muscles in the body, even though they were not located correctly and were mainly drawn into the arms and legs. Pupils were unable to name the muscles both before and after the teaching period (Table 5).

Table 5. The frequency of the inclusion of muscles in the pupils' drawings prior to and after the teaching period.

Musculature	Before teaching	After teaching
Muscles (generally)	17	14
Abdominals	1	
Quadriceps	1	
Peroneus muscle	1	
Biceps		1

In the interviews the pupils referred to the muscles more often and they knew their location. They were unable to explain the role of the muscles before being taught but showed a more accurate understanding of their function after teaching.

There were no changes in the drawings concerning blood circulation either before or after teaching (Table 6). The heart as an organ was quite systematically known before and after the studying project. It was clearly located in the drawings but some students used a non-anatomical shape. The purpose of the heart was well known. However, prior to studying the pupils did not relate the heart to vessels or the blood circulation system, it was considered as a separate organ. Despite having studied the blood circulation system and the heart was explained as being a pump in that system, this area was not concretely structured in the pupils' minds. The structure of the heart was described only by a few of the pupils.

Before the lessons the blood vessel was unclear as a concept. The pupils either did not have any term to describe the blood vessel or they used the concept of the intestine. The reason for this is the mixed understanding of the names of organs: in the Finnish language these concepts sound very similar (*suoni ja suoli)*. The concept was correctly used after the teaching period.

Table 6. The frequency of the inclusion of the organs of the blood circulation in the pupils' drawings prior to and after the teaching period.

Blood circulation	Before teaching	After teaching
Heart	20	24
Blood vessel	7	7

In the interview after teaching, the blood circulation system was linked to the transportation of nutrition and oxygen. The pupils had a multidimensional understanding of the blood circulation and the role of the heart in that process. Blood was seen as being essential for life and thus the heart was seen to be the most important organ of the human body (see Table 6 and Table 7).

Table 6. Teresa's interview before teaching.

Intw:	Here you have drawn the heart. What is the task of the heart?
Teresa:	It pumps blood for the body
Intw:	Where does it pump blood?
Teresa:	Everywhere.
Intw:	Why does a human need blood
Teresa:	For living, so that we can do things and that we can survive

Table 7. Teresa's interview after teaching.

Intw:	What is the role of the heart?
Teresa:	It pumps blood for the body.
Intw:	How does it happen? How does the heart work?
Teresa:	It goes through the artery. The heart pumps blood along the vein and the artery to the body. Blood with oxygen flows to the body and blood without oxygen flows back to the heart.
Intw:	Why does the human body need blood?
Teresa:	I do not know exactly, but it is needed for life and it keeps the body warm enough.

Before the lessons the pupils did not describe the heart as being a muscle, but afterwards this was understood. The pupils often modelled the heart as being a pump which works automatically like a heart muscle. The interrelation between the main blood vessel artery and veins also became clearer during the project.

During the study the clearest changes in the pupils' conceptions occurred in the case of the brain, senses and nervous systems. Before being taught, pupils systematically drew brains, but were not able to specify the parts of the brains. The senses were not systematically drawn into the pictures. After the lessons the brains were drawn in the same way as earlier, but parts of the brain were also named. In addition, the senses were drawn into the pictures more often than before (Table 8). The pupils had not mentioned anything about the nervous systems before the lessons. Afterwards the nervous system and its connection with the brain was shown in many drawings.

Table 8. The frequency of the inclusion of the organs of the brain, senses and nervous system in the pupils' drawings prior to and after the teaching period.

Brain, senses and nervous system	Before teaching	After teaching
Brains	25	22
Cerebrums	1	4
Cerebellums	1	7
Eyes	6	11
Nose	5	12
Mouth	5	11
Ear (aural)	1	11
Nerve/nervous system		10
Spinal cord		5
Interbrain		2
Pituitary		3

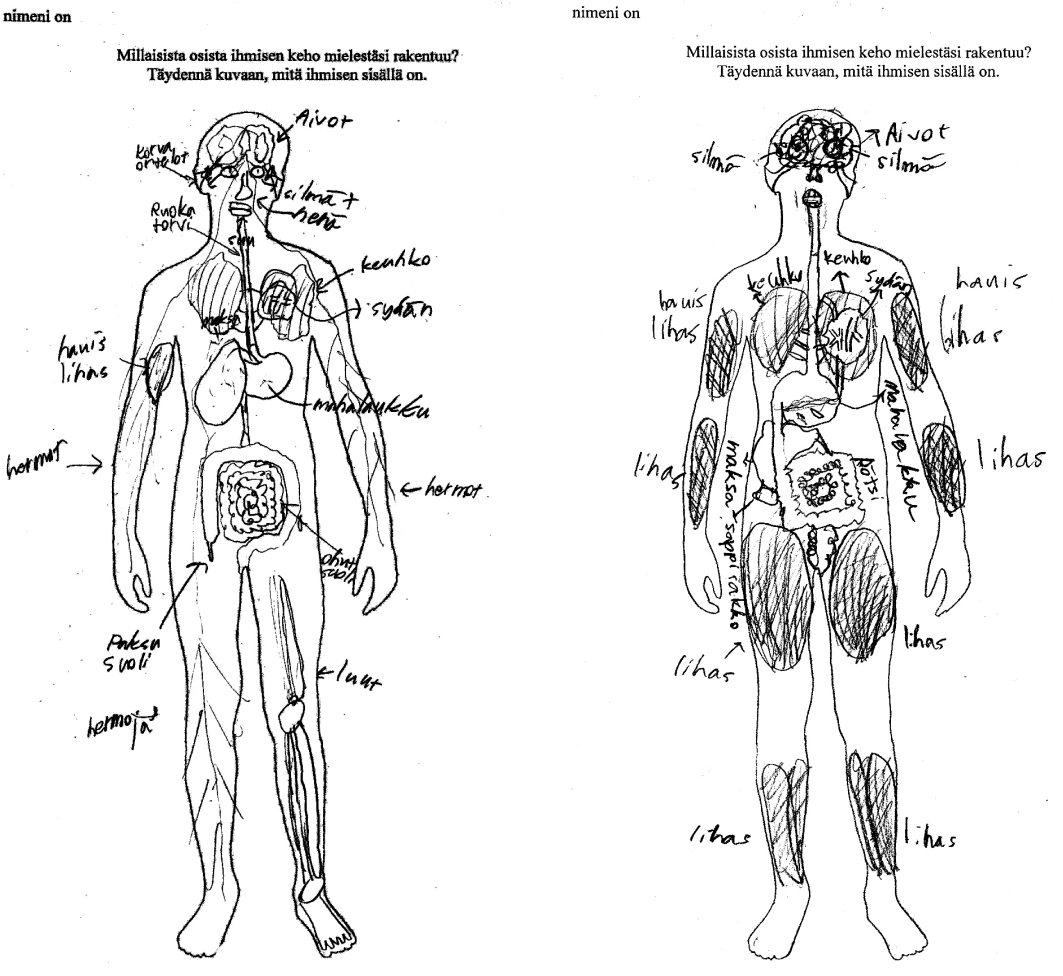
In the interview the pupils mentioned that in particular they had learned about brains. They learned about the functions of brains, but also about their structure. Thus in the drawings and interviews after the lessons, the structure of the brain was accurately described.

The most noticeable the pupils' conceptions were in the case of the digestive system. Before instruction the pupils mentioned many organs of the digestive system, but their understanding of it deepened during the study (Table 9). The drawings were filled in more carefully in terms of digestion and the stomach was one of the organs which were known almost by everyone. After their studies the pupils were able to draw the digestive system completely. The different organs of the digestive system were included into the drawings as a continuum. Especially the role of the small and large intestines were mentioned more correctly after the studying process.

Table 9. The frequency of the inclusion of the organs of the digestion system in the pupils' drawings prior and after the teaching period.

Digestive system	Before teaching	After teaching
Tripe (stomach)	21	24
Bowels	13	8
Liver	10	22
Kidneys	4	6
Small intestines	1	12
Large intestine	2	11
Back passage (rectum)	3	10
Spleen	1	1
Bladder	9	6
Gullet	9	12
Salivary glands		7
Pancreas		1

After the teaching period, the liver and its role were more systematically included in the drawings and explanations. The pupils became more aware of the system of digestion and how the food is used in the body. The process of absorption also became evident after studying it. The pupils' ability to see human body as a more systemic after teaching is seen for example in Edward's drawings (Figure 1).



drawing A drawing B

Figure 1: Edward's drawings prior to (drawing A) and after (drawing B) the teaching period.

The respiration system was quite unclear to the pupils before teaching, although almost 80 % of the pupils had named the lungs (Table 10). There were no signs either in the drawings or interviews about understanding how respiration happens and which organs are essential. After the studying project, pupils were able to explain gas changing and mentioned the role of oxygen.

Table 10. The frequency of inclusion of the organs of gas respiration in the pupils' drawings prior to and after the teaching period.

Respiration	Before teaching	After teaching
Lung	22	23 (1)
Windpipe	4	9
Bronchial tube	1	1 (1)
Solar plexus		1
Alveolus		2

There was very little proof about understanding how organs exist as related structures within organ systems. The organs were mostly presented as separate units. In addition, before studying the pupils were not able to clearly explain the function of those organs nor had they understood the different functions of the systems. After instruction, the pupils' drawings were more detailed and the amount of organs increased noticeably in many drawings. Drawings were carefully filled in and the organs were systematically named. In addition, we found some signs of a holistic understanding of digestion. In the interview, most of the pupils were able to explain the function of those organs and their relational interaction with each other.

In terms of conceptual change, the pupils' conceptions of the human body became richer and more systemic. The pupils were able to mention several different organs and explain their purpose for the body. In the drawings the organs were clearly related and correctly drawn with each other. The students' conception reached the epistemological changes but clear ontological changes did not occur in this data. The pupils, who had prior knowledge about the human body, were able to become more specific during the study. Those pupils who earlier did not have such a clear understanding of the human body, often gathered more knowledge but did not clearly change their way of thinking about the systems of organs.

Discussion and Implications for Teaching

This study was conducted as an intervention study in which pupils' conceptual change process was analysed. This study has many similar results to those found in the studies of Reiss *et. al.* (2002) and Carvalho *et. al.* (2004). Before the teaching period, the understanding of the human body and its organs varied a lot among the pupils. The pupils' conceptual understanding of the human body changed during the study. Although the pupils had quite a lot of information about the organs of the human body, the pupils drew and explained organ systems more accurately after the studying project. The digestive system was one of those organ systems best presented (see also Reiss & Tunnicliffe, 2001; Óskardóttir, 2006), but also the respiration system and brain were drawn and described in more detail after instruction. The digestive system seems to be concrete enough for understanding the system, but the brain is very interesting because of its abstract nature. During the teaching the issues which affect for the brain and nervous system were considered within the issues that are very actual for the young people.

This study has shown that we need research concerning the functions of the human body especially from the view point of conceptual change. It seems that pupils can easily assimilate the detailed parts of information, but understanding the function needs careful consideration. In addition, it seems to be significant that correct concepts are used and learned during studying. The five week studying period supported the pupils' conceptual change process, but to achieve deeper changes more work would have been needed.

The pupils were very interested in studying the human body and its systems. In Finland, this topic is studied once in grade 2, but the main focus on the function of the organs is in year five at primary school (11 to 12 years). The pupils enjoyed and learned from those parts of the project which were conducted practically and were enjoyable. STS teaching approach provided a good context for inquiry based learning. Conceptual challenges are also important for the process of conceptual change.

Methodologically, the study strengthened the view that the combination of drawings and interviews increase the validity of the research. Both parts of the data gathering methods elicited information, which differed from each other. Reiss *et. al.* (2001) made an international comparative study using drawings. They received data in which pupils also expressed their emotional feelings. In our study, all pupils expressed themselves through anatomy, although the interviews revealed that the pupils did not draw all they knew. Thus interviewing pupils increased the credibility of research in terms of conceptual understanding.

The STS teaching approach in this manner seems to enhance the pupils' conceptual understanding of the human body but it is also a motivating learning approach. It seems that when the processes of the organ systems were concretely modelled and tested, pupils had a better view of these systems. In this research, the digestive system seemed to be the system which was learned effectively. In order to understand the digestive system, the process was modeled on a t-shirt on a concrete scale. After instruction the pupils had a very clear and concrete view of the system. Based on this study it seems that multifaceted learning methods motivate pupils to concentrate on the teaching and therefore it helps their learning.

In this research, before starting the teaching, the pupils' previous knowledge was gathered through drawings. This method seemed to be a relevant approach for gathering background information for the teacher but also in activating the pupils to think about their body and systems of organs. In the school context there are limited possibilities to use lessons for one particular theme, so in the case of biology, it seems to be very important to know in advance how pupils express their understanding and note the concepts which have already been recognized.

During instruction, not only organs and the organ systems were studied, but also the physical significance of food and exercise for health. According to STS teaching, studying and learning should be integrated into everyday life activities which young people concretely experience in their own lives and which are significant for themselves (see Aikenhead, 2000). The pupils also expressed the issues in the interviews after studying. The pupils individually found a good reason why it is important to understand the human body and why healthy food is needed.

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