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STUDENTS' IDEAS ABOUT THE HUMAN BODY AND THEIR ABILITY TO TRANSFER KNOWLEDGE BETWEEN RELATED SCENARIOS

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ABSTRACT

Analyses of students' ideas about the organ system in the human body and how these relate to their thoughts about living a healthy life are presented. The study concerns 9th grade students (15/16 years) in Sweden. The empirical data consists of drawings and answers to written questions, both open and multiple-choice, and interviews with students and teachers. Comparing explanations of a well known scenario (eating a sandwich) to other that are less often discussed (taking a painkiller and drinking water) we report that it is difficult for the students to transfer knowledge of pathways in the digestive system shown in explanations of the sandwich-scenario to the other scenarios. Most difficulties are shown for explanations of the drinking of water, since these explanations require connection of three different organ systems. More than half of the interviewed students believed that there is nutritious substance in water, but most of them were unable to specify what it would be. The students with the most developed understanding of the painkiller pathway were satisfied with taking medical substances to elude pain, and were not interested in other alternatives.

Key words: students' ideas, organ system, painkiller, horizontal transfer.

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INTRODUCTION

Background and Framework

Swedish students' knowledge about the function of the human body is explored in this study. There are two foci for this article. We focus on students' ideas about what happens in the human body when you eat food, drink water or take a painkiller and on related question affected by their ideas. The second focus is the analysis of students' capability to transfer ideas horizontally between different scenarios on the same organizational level. Students' responses to questions about three scenarios are analysed and compared in relation to the morphology and physiology of the human body.

According to the Swedish curriculum, the students should at the end of the ninth grade have knowledge about the cells, the organs of their own bodies and how the organ systems function together. They should know about different aspects of health, e.g. possible effects of addictive substances, and be able to take part in discussions of the importance of regular exercise and good health habits (Skolverket, 2009). Several studies have confirmed that the students have knowledge about the digestive system (Carvalho *et al*, 2004; Garcia-Barros, Martinez-Losada and Garrido, 2011; Mathai and Ramadas, 2009; Osborne *et al*, 2004; Reiss *et al*, 2002; Tunnicliffe 2004). The Students' knowledge of the digestive system is more developed compared to the gaseous exchange system and the skeletal system (Reiss *et al*, 2002), the excretion system (Tunnicliffe, 2004), the respiratory system (Mathai and Ramadas, 2009). Even before the compulsory school the children have some ideas about the digestive system (Martinez-Losada and Garrido, 2011). Notice, that most of the studies above are focusing on younger students. The level of sophistication of students' answers has been shown to depend on how questions are given to them. When asked specifically to draw the urinary organs the students performed better compared to when asked to draw organ systems in general (Prokop, Fancovicová and Tunnicliffe 2009; Prokop and Fancovicová, 2006; Khawaja and Saxton, 2001). Hence, the manners in which questions are put to the students have significant effects, not only how the questions are formulated, but also how the students are expected to answer (writing, drawing or speaking). In a Swedish study among grade 9 students it was shown that the students had implicit ideas that they did not express in written responses, but were able to express in interviews concerning explanations involving the digestive system and the circulatory system. But, this well established pattern of more details being given in interviews

compared to written responses was not shown concerning explanations of the drinking of water, an explanation involving three different organ systems. The students did not give more details in the interview situations, instead their responses there were less sophisticated there (Granklint Enochson and Redfors, 2011).

In another study it has been seen that students had difficulties in interpreting diagrams of the systems. It was easier for them to read short texts, and the difference between students' understanding from diagrams and texts was larger for the weaker students (Mathai and Ramadas, 2009). The textbooks' visual presentations of the organ systems are of importance for learning and many have been found to be complex and confusing for the students (Carvalho, Silva and Clément, 2007). Carvalho, Silva, Lima, Coquet and Clement (2004) found that young students (9/10 years) have problems in understanding the role of the blood as a transportation system. Even adult students have problems explaining the role of the circulatory system (Clement, 2003). In another study by Rowlands (2004), ten-year-old English students were asked to explain what happens to the food they eat. There were no indications that the children had any knowledge about the chemical change of the food. Many of the students thought that food could be separated by the body into two parts – healthy and unhealthy food. With some help from the teacher, the students understood that food is broken down into small pieces. Most of these students had an understanding that the circulation system was involved in the process. Seven of the twenty-five students described two separate systems in the body, one for solid food and one for drinks (Rowlands, 2004). Teixeira (2000) found that children could not connect the organs in the body with their functions until they were 10 years old.

There is a shortage in the textbooks concerning the link between different organ systems. The link between the digestive system and the circulatory system are the most commonly described link, but the connections to the urinary system are seldom expressed (Carvalho and Clement, 2007). To extend these reported results with the aim of investigating the consistency of the students' explanations across different scenarios we set out to investigate explanations given by Swedish school students when asked about processes in the human body in scenarios where the expected explanations would involve two or three systems, i.e. the digestive system, the circulatory system and the excretion system.

Ten-year-old children in England and Greece understood that too much fat was not good for the health. It appeared that children had a hard time understanding that liquid fat also is fat.

Furthermore, it was found to be a common idea that fat food has no vitamins. They also over-estimated the amount of vitamins in fruits, and underestimated for meat and fish (Turner, Zimvrakaki and Athanasiou, 1997). Even if the students knew that the body needs carbohydrate and fat it was difficult for students in age 8-12 to understand the function of carbohydrate and fat in the human body (Mann and Treagust, 2010).

Purpose of the study

We are reporting here on an investigation that looks into the consistency of students' answers across scenarios and connects students' views of body functions and health by investigating the relation between the quality of students' explanations of processes in the human body and their ideas about some related issues. The focus of this study is on the outcome of the students' learning at the end of the 9th year (15/16 y) of compulsory school. We use students' individual responses at the end of compulsory school to analyse the ideas developed through individual, social and societal processes in and out of school. All three areas of learning are deemed to be of importance (Driver, Asoko, Leach, Mortimer & Scott, 1994), but this study is focusing on the formal learning in school. Ideas that individual students hold are studied through written and oral statements. Hence, our position is that students have their own core of constructed knowledge, but are affected by the influence of external social factors and artefacts (Vygotsky, 1999; Oskarsdottir, 2006; Mortimer and Scott, 2003). This project is setup to study individual students' possibilities to transfer ideas between different scenarios within a given content area in biology. Transfer is a concept focusing on how students use and transfer their ideas of a phenomenon from one context to another (Mayer, 2002; Salomon & Perkins, 1989; Spiro, Collins, Thota and Feltovich, 2003). Schönborn and Bögeholtz (2009) define horizontal transfer as the ability to transfer ideas from one context to another on the same organizational level (for example, different body systems on the macro level). Vertical transfer, however, refers to the ability to transfer ideas between different levels of the organization (for example, between macro and micro level).

The overarching aim of the project is to analyse possible correlations between the students' knowledge about the function of the human body and their arguments about some related question. A specific aim is to look for horizontal transfer between explanations of scenarios (sandwich and painkiller) requesting two systems, the digestive system and the circulatory and transfer to

explanations of a scenario (water) that requests three systems; digestive system, the circulatory system and the excretion system. Three research questions have been formulated.

RQ1: How do the students explain what happens in their bodies when they eat an open sandwich, drink water or swallow a painkiller?

RQ2: Are the students transferring knowledge between the different scenarios? If so, how can the students' explanations of the painkiller- and water-scenarios be described, based on a categorisation of their explanations of what happens in their bodies when they eat an open sandwich?

RQ3: What correlations can be seen between the students' knowledge about the function of the human body and their answers to related questions?

METHOD AND ANALYSIS

Different kinds of data were collected in order to answer the research questions. Overview of data collection is shown in the figure 1. Templates with an outline of a human body, open questions, multiple-choice questions and interviews were used. The templates gave the students the possibility to answer by drawing, writing or both. Hence, the students could follow their preference in answering the template questions. Students' drawings as a method have been used before (e.g. Reiss *et al*, 2002; Tunnicliffe, 2004; Rowlands, 2004; Teixeira, 2000). Rowlands (2004) and Teixeira (2000) used it in connection to interviews with young children (10y or younger). Written open questions were used here to get the students to formulate explanations based on their own ideas. The multiple-choice questions were focusing on the students' knowledge, and have previously been used in TIMSS 1996 (Skolverket, 1996) and IEA 1983 (Skolöverstyrelsen, 1988) in Swedish schools. The interviews with the students were done to get a richer and deeper understanding of the students' ideas.

The study includes 88 Swedish students in the ninth grade (15/16 y) in a school located in a municipality with approximately 7000 inhabitants. This municipality is part of a city with over 100 000 inhabitants. There were two main reasons for choosing this school. The first is that the community is typical for Sweden concerning parents' income, amount of unemployment and percentage of immigrants (SCB, 2007). The second reason was that the pilot study, where another

school also participated, did not show any major variations between the two schools, even though the other school was located in another part of the country. The study was therefore finalised with only one school. All the ninth grade students that were present in the school on the day of the data collection participated in the paper and pencil tasks. Twenty of 108 students were absent that day.

Seven teachers who had taught the students in subjects where the function of the body and nutritious[1] substance are part of the syllabus were interviewed. The seven teachers taught Biology (5), Home and Consumer Studies (1) and Physical Education and Health (1). The reason for interviewing the teachers was to confirm that the students had been taught about the digestive, circulatory and excretion system as well as the content of the related questions. It was also important to confirm that none of the teachers had explicitly talked about painkillers in relation to the digestive and the circulatory systems, since this scenario was meant to be new for the students. We asked the students about a commonly used specific painkiller containing the active substance *paracetamol*. The uptake of *paracetamol* is in the intestines, but since this is the dominating "place" for other active substances too, the type of painkiller is not critical.

All data was collected in the end of April and May, when the students had nearly finished their time in compulsory school. In Sweden the school year ends in the beginning of June. Three sheets of paper with the same template of a non-gender specific human body, but with three different questions were distributed. The questions were: What happens in your body when you 1) eat an open sandwich 2) drink water 3) swallow a painkiller? Each student got two of the three template-questions, because the pilot study (Granklint Enochson, 2008) showed that the students had difficulties staying concentrated for the third template-question. Irrespective of in what order they were presented, the explanations of the third template were always less detailed. The pairs of templates were passed out randomly to the students, and we have an equal number of answers for each question. Additional open questions were given at the bottom of the template-sheets to allow students to formulate their own explanations. The questions concerned how water and lack of nutritious substance affect the body, and about the alternatives to painkillers in getting rid of the pain, see Appendix A. Since the students only got two of the three body templates, only two sets of

[1] Nutritious substance is defined as: proteins, carbohydrates, fat, vitamins and minerals in this study. The definition is coherent with the biology textbook the students were using. The same definition is used by the National Food Administration, SLVFS 1993:21.

the subject related open questions were answered by each student. All the students answered the multiple-choice questions from TIMSS 1996 (Skolverket, 1996) and IEA 1983 (Skolöverstyrelsen, 1988) directly after having completed the template-sheets. The multiple-choice questions covered the students' knowledge about nutritious substances and some body functions; see Appendix A for the questions.

The drawn and written answers to the template-questions were analysed ideographically (Driver *et al*, 1994) with a commitment to reflecting each student's position as written and drawn, rather than evaluating in terms of a set of predefined positions. A system of categories for explanations used by the students was generated through repeated reading of the answers to the template-questions. During the analysis of the templates several categories of answers occurred. Some of the categories had characteristics in common and they were possible to cluster into four main categories after discussions with other researchers. We aimed to establish a set of scenario-independent general categories that could be used to categorise answers from all the three scenarios. The categories were formulated based on responses to the template-questions only. Furthermore, each written and drawn answer to a template-question was categorised as one statement, i.e. only one category was assigned per template-question and student.

The categories represent a measure of resemblance to scientific explanations, and have an internal hierarchy based on a comparison with scientific explanations. The categories have similarities to the ones reported by Clément (2003) and Tunnicliffe (2004), but we have chosen more general descriptions. The reason for this is that we wanted to use the same categories for all student explanations, regardless of the scenario. This gave us the possibility to answer research question two about the transfer of the students' ideas. The categories are:

A. No answer or answer not related to the question
B. Non-scientific descriptions based on alternative ideas of the organ system
C. Descriptions following a scientific explanatory model – important parts missing
D. Descriptions following a scientific explanatory model – important parts included

The first category (A) captured the students who did not answer the question or gave answers associated with other issues. The second category (B) captured students who gave answers that were non-scientific descriptions based on alternative ideas of the organ system. The categories C and D

were used for templates that partly or fully contained the expected systems. The expected systems were:

Sandwich	–	digestive and circulatory systems
Painkiller	–	digestive and circulatory systems
Water	–	digestive, circulatory and excretion systems

The categorisation informs on whether students can transfer ideas between the "sandwich" and the "painkiller" scenarios, and whether they can extend their explanations to involve three systems for the water-scenario. The sandwich scenario is taught in school, the water-scenario had been indirectly taught through discussions of the kidneys and cells. The uptake of painkillers had not been taught to the students. The categories from the analysis of the drawn and written answers to the template-questions were used to analyse the open questions, the multiple-choice questions and the interviews. The categorisation above is emphasizing different levels of understanding of the used scientific models. Hence, for students in C and D we expected a more pronounced positive correlation with their answers to the related questions compared to the category-B students. We use the term circulatory system for the cardio-vascular system, since this corresponds to the term used by the Swedish students.

A description was defined as following a scientific explanatory model if it contained a coherent explanation in accordance with a use of scientific explanatory models expected from these students (15/16 years) in Sweden. The expected scientific level is in accordance with the Swedish national school curriculum that stipulates the following learning goals for the human body and health, to be obtained by the students at the end of the ninth grade (15/16 y).

Biology

Students should concerning Nature and Man:

- have a familiarity with how cells are built up and how they function,
- have a familiarity with the organs of their own bodies, their systems and how they function together
- have a knowledge of the effects of addictive substances on health, concerning use of knowledge
- be able to take part in discussions on the importance of regular exercise and good health habits.

Home and Consumer Studies

Students should:

- be able to plan, prepare, arrange and evaluate meals with respect to costs, health, environmental and aesthetic values

Physical Education and Health

Students should:

- understand the relationship between food, exercise and health, and be able to apply a knowledge of ergonomics in everyday situations

(Skolverket, 2009)

Nutritious substance is not explicitly mentioned in the curriculum goals. However, nutritious substance is implicitly present in the formulation of the goals and used in teaching. All students in our sample had through teaching been exposed to the scientific models required to provide what we have called 'descriptions following a scientific explanatory model' during their years in school.

RESULTS

The presentation of the results is following the structure of the three scenarios, including templates with connected open, multiple-choice, and interview questions. We begin with the open sandwich. Then continue with water, and end with the pathway of the painkiller. The section concludes with a comparison of the different questions. Based on the interviews with the teachers we can conclude that all the students had been taught about the digestive, circulatory and excretion system. None of the students had explicitly been taught about painkillers. The question about nutritious substance in food and water had been discussed in the two subjects *Biology* and *Home and Economics*.

Sandwich

The template question "What happens in your body when you eat an open sandwich?" were answered by 55 students. We find, similarly to results in several other studies (Rowlands, 2004; Reiss *et al*, 2002; Teixeira, 2000; Osborne *et al*, 1994), that students have a fair knowledge about the digestive system. Therefore the analysis of the sandwich-question can be used as a basis for the comparisons with the painkiller and water scenarios, and the students' ability for transfer.

All the students except one (A) were categorised as C or D. There were 24 students in category D, they drew throat, stomach, intestines (digestive system) and mentioned that the circulatory system connects to the intestines, see example in Fig. 2. In category C there were 16 students (total of 30 students in the C category) who wrote or drew a digestive system but they were not explicit about the circulatory system. The rest of the category C students drew or wrote parts of the digestive system. In the interviews nearly everybody talked about the connection between the digestive system and the circulatory system. There were no statements categorised as B for the sandwich scenario in the written and drawn templates or in the interviews.

The students were given multiple-choice questions to investigate if a correlation could be seen between their answers to related questions and their knowledge about the body. For the question about why it is important to eat fruit and vegetables (see Appendix A) nearly all the students (84 of 88) knew that it was because fruit and vegetables contain a lot of vitamins and minerals, hence no correlation could be seen in this case. This is in agreement with earlier results (Turner, 1997; Turner *et al*, 1997). Another multiple-choice question covered protein content in different foods, see Table1.

The students were asked to estimate the foodstuff that contained the most protein, and 29 out of 55 students answered chicken, but 20 students answered potatoes. Also in the case of the "protein-question" shown in Table 1 it was not possible to see any correlation between the level of knowledge about the body and answers to the multiple-choice question. There were no significant differences for students with good knowledge (D) and those displaying less detailed ideas (C) about the body, and there were no students in B for this scenario,

Painkiller

The painkiller-template was developed to investigate students' capabilities to transfer knowledge. We used a scenario not used during teaching in school. The template-question was "*What happens in your body when you eat a painkiller?*". The uptake of painkillers had not been taught. We found answers representing all four categories A to D. 31 of the 59 students' belonged to category C. The students in the C category had an idea that the painkiller went to the throat and further to the stomach, but none of them mentioned the intestines. However, 21 of the 31 students described that the circulatory system was connected to the stomach, see figure 4.

There were 10 of the 59 students whose descriptions included a digestive system with throat, stomach, intestines and the circulatory system. These ten students were categorised as D. In category B there are 11 students who explained their ideas about the pathway of the painkiller in a non-scientific way. These descriptions start with the mouth, and then the painkiller substance is more or less directly distributed to the whole body. There were seven of the 59 students who did not answer the question or gave an answer not related to the question, category A.

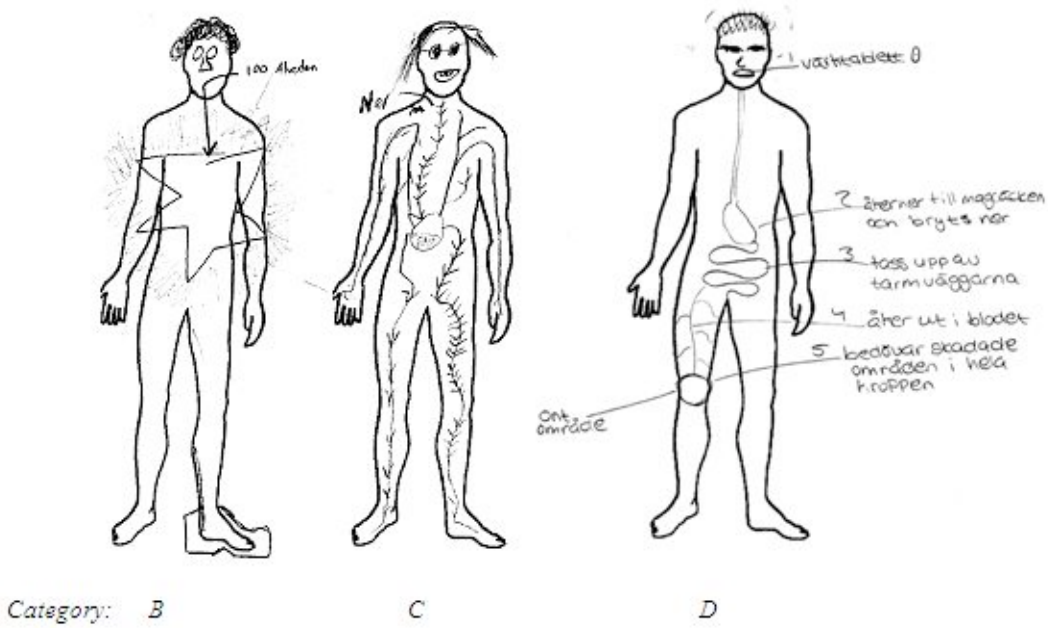


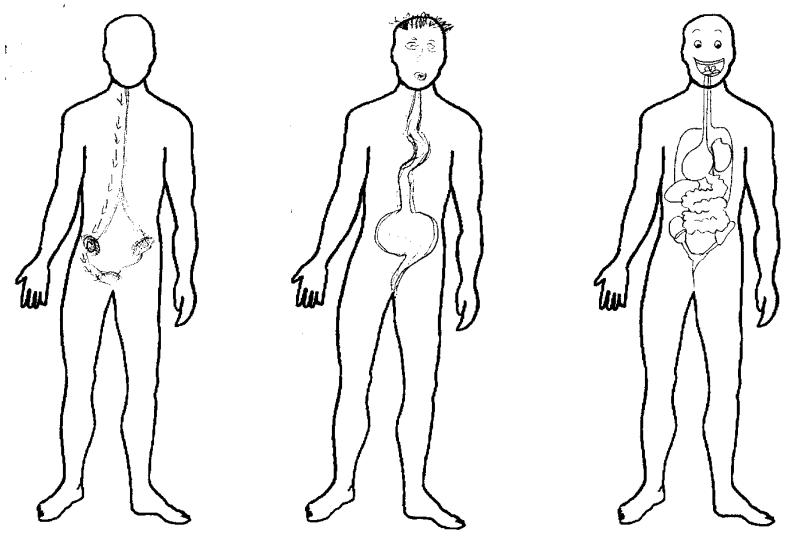
Figure 1. **Examples of drawings that were categorized as B, C and D for the question "*What happens in your body when you swallow a painkiller?*". B represents explanations that were not scientifically sound. For C parts of the digestive system with throat, stomach and circulatory system were described. Students that were able to describe the digestive system with throat, stomach and intestines together with the circulatory system were categorised as D.**

The painkiller-template was accompanied by an open question about alternatives, i.e. "*If you are in pain, are there any alternatives to taking a painkiller to alleviate the pain?*". The students with a more advanced understanding of a painkiller's way through the body (category D) were those who believed that pills primarily could be replaced by pain-relieving emulgels, so their first choice was another medical substance. These students were not interested in alternatives such as massage, take a nap and so on. Therefore they gave fewer alternatives to painkillers in the open question and in the interviews than the other students. They showed no reluctance to using medical substances.

Hence, we see a positive correlation between level of explanation and answers to the multiple-choice question.

Water

Nearly all of the students in the study had difficulties explaining the connection between the digestive system, the circulatory system, and the excretion system when asked about what happens in the body when they drink a glass of water. It was only 2 of the 55 students who drew and/or wrote about the digestive system as connected to the circulatory system and the kidneys. Only these two students belonged to category D (see fig 3). The category D requires an explanation involving three systems for the water scenario. The students categorized as C drew the digested system or parts of it (31 of 55 students). None of the students in category C introduced the kidneys in their drawings or writings. It was revealed that one group (13 of the 55 students) had ideas about "new/alternative" organ system for fluids – not scientifically sound. They were all categorised as B. Most of these students drew a tube from the mouth connected directly to the kidneys, see fig. 3. No one, not even the category D students, included the micro level, e.g. cells and molecules in their explanations.



Category: *B* *C* *D*

Figure 2. Examples of drawings that were categorized as B, C and D for the question about what happens in the body when one drinks a glass of water. B represents explanations that were not scientifically sound. For C *parts of the digestive system with or without the circulatory system were described. Students that were able to describe the digestive, the circulatory, and the excretion systems were categorised as D.*

Answers to the multiple choice question "What is the main function of the kidney?", see Appendix A, were analysed to investigate possible correlations between answers to the template question about water and answers about the kidney. Seven out of thirteen students (54%) that belonged to category B had the right answer to the kidney-question. In category C there were 22 of 31 students (71 %) who marked the correct alternative. Notice, that the students in category C did not draw the kidneys or write about them on the template in contrast to students in category B who drew the kidneys as shown in figure 3 (see table 2.). Both the students in category D gave the correct answer to the kidney-question. Taking into account that the number of students is very low in category D we can see a positive correlation between level of explanation and answers to the multiple-choice question.

TABLE 2. The students' answers to the multiple choice question "*What is the main function of the kidney*?".

	Categories				
What is the main function of the kidney?	A	B	C	D	All
To produce antibody against illness	1		1		2
To decompose food	1	3	4		8
To circulate the blood		1			1
To produce red blood corpuscles	2	2	4		8
To clean the blood from waste products	5	7	22	2	36
TOTAL	9	13	31	2	55

**The students are grouped in columns after the categorisation of their responses to the template question. A is students with no answers to the template question. B represents explanations that were not scientifically sound. For C parts of the digestive system with or without the circulatory system were described. Students that were able to describe the digestive, the circulatory, and the excretion systems were categorised as D. The scientifically correct answer is in bold letters.*

Transfer of ideas

As mentioned above we were looking for the students' ability to use knowledge shown in explanations of the sandwich scenario and describe the body's digestive and circulatory systems for the sandwich and painkiller scenarios. The analysis show that it is much more difficult for the students to use their ideas of the digestive system in explanations of the painkiller-scenario – not

taught to the students – compared to the sandwich-scenario which was relatively well known for them (see table 3).

TABLE 3. A comparison between the students' answers in two scenarios refer to the digestive and circulatory systems

	A	B	C	D	Total
Sandwich	1 (2%)		30 (55%)	24 (44%)	55 (100%)
Painkiller	7 (12%)	11 (19%)	31 (53%)	10 (17%)	59 (100%)

Hence, the students show a limited ability for horizontal transfer from a well-known to a new scenario.

In the water-scenario the students were expected to link the digestive, circulatory and excretion system. The analysis showed that the students struggled to explain what happens in their bodies when they drink water (see table 4).

TABLE 4. Students' answers in a scenario refer to the digestive, circulatory systems and excretion systems

	A	B	C	D	Total
Water	9 (16%)	13 (24%)	31 (56%)	2 (4%)	55 (100%)

Notice that it was even harder for them to extend their explanation from the sandwich-scenario to the water-scenario requiring three systems, compared to the transfer between the sandwich and painkiller-scenarios described above.

DISCUSSION AND IMPLICATIONS

The students were familiar with the circulatory system in the human body. Nearly everybody had some ideas about the function of the blood in the human body, and half of the students spontaneously connected the digestive system with the circulatory system. This result differs from what is reported from previous studies, where more difficulties have been found about the role of the circulatory system (Rowlands, 2004; Clement 2003; Carvalho *et al*, 2004).

In agreement with earlier studies we have concluded that the investigated students have better knowledge about the digestive system than the excretion system (Reiss *et al*, 2002; Tunnicliffe, 2004; Clement, 2003, Teixeria, 2000). Based on this we have investigated the students'

ability to transfer knowledge from a well-known scenario "the eating of a sandwich" to explanations of the different painkiller- and water-scenarios, that had not explicitly been taught to the students. The painkiller-scenario had not been discussed at all, and the water-scenario had only been indirectly addressed during discussions of the kidneys and the cells.

We have seen that, that it is difficult for the students to horizontally transfer knowledge of the digestive system to other less well-known scenarios, i.e. from the sandwich- to the painkiller-scenario. Only ten of 59 students were able to transfer their ideas about the human anatomy and the digestive system from the sandwich- to the painkiller-scenario. Another type of horizontal transfer is required when the students are asked to explain what happens in the body when you drink a glass of water. This proved to be even more difficult for the students, and only two of 55 students were able to incorporate three different organ systems; the digestive system, the circulatory system and the excretion system, in their explanations. The conclusion is that students struggle to transfer their knowledge of the digestive system from the sandwich- to the painkiller-scenario, but it is even more difficult for the students to connect several different organ systems in one explanation. Hence, it was, in this case, easier for the students to transfer information across scenarios than to see the relationship between different organ systems in the body. However, only 10 students (17%) could give as good explanations in the painkiller scenario as they did concerning the open sandwich. This confirms earlier results (e.g. Redfors and Ryder, 2001; Magntorn and Helldén, 2007; Schönborn and Bögeholtz, 2009) that report on students struggling to use known explanatory models in explanations of new scenarios.

The Swedish curriculum emphasizes the importance of students having knowledge about the cell and its role in the processes of the human body. However, none of the students mentioned the cells in their explanations of the scenarios. They never mentioned any connection between the cells of the body and the digestive or excretion systems in their written answers or in the interviews. The students did not use concepts from the microscopic level at all. In spite of the fact that the microscopic explanatory level was used in the teaching of biology according to the teacher interviews. One reason for the students not doing this could be difficulties with transferring their knowledge from the level of organ systems to the level of cells, molecules and atoms – a difficulty that has been reported earlier by Schönborn and Bögeholtz (2009). The difficulties the students showed in explaining the water-scenario could be partly explained by the fact that they seem to stay

in the organisational level of systems, and do not discuss the cells and the pathway of water molecules. We believe that an explanation involving three systems is easier to produce from a perspective of the role of the cells.

Carvalho, Silva and Clément (2007) point out those textbooks seldom make it clear how the different parts of the digestive system are linked together; the circulatory system is, for example, seldom clearly associated with the digestive system. We have in this study seen another missing connection, namely with the glands. The students do not connect them to the digestive system. Only a few students' mention glands, e.g. liver and pancreas, but none of them write anything about their function. In the textbook that the students were using the glands are only briefly presented. The liver, for example, is only presented in one of the pictures together with the digestive system and is only mentioned twice in the text.

The categorized students' answers concerning what happens in the body when they eat a sandwich were not correlated with their answers about nutrients. They demonstrated good knowledge of the digestive system in their explanations of the sandwich-scenario. But, for example, in the multiple-choice questions about protein content, only about one third of the students knew that chicken contains more proteins than apples, rice, bread and potatoes, see Table 1 and Appendix A. However, nearly all students knew about vitamins, even though vitamins and proteins had been taught similarly according to the teacher interviews. This indicates that their own personal experience about vitamins in everyday life plays an important role also for the formal learning in school (Vygotsky, 1999; Oskarsdottir, 2006; Mortimer and Scott, 2003; Leach and Scott, 2003; Driver *et al*, 1994).

The students with the most developed understanding of the painkiller scenario were the students who were not pleased with alternatives to taking painkillers. These students were more positive to the use of other types of painkillers compared to the other students. The dominating view among all the students (even the students who were not pleased with alternatives) was that it is dangerous to take painkillers, some of the students emphasized that the danger with taking painkillers is that it affects the immune defence. Maybe the students had the inflammation inhibitory effect in their mind, but some of the answers indicate that they confuse painkillers and antibiotics. Possibly these students were thinking about other medicines that are both pain relievers and have effects on inflammations. All the students' answers to why it can be hazardous to swallow

a painkiller had in common that they lacked personal experience of the possible problems they mentioned, e.g. liver damage.

From a methodological point of view the present report is showing strength in giving students the possibility to both write and draw on the templates. Only a few students (two students) refused to answer the questions and we got detailed descriptions on the templates. Most of the students used the opportunity to both draw and write on the templates. We think the mix of methods used during the study helped students to be alert during the whole investigation and it gave them the opportunity to answer in a way that suited them.

Based on our results we suggest that it would be interesting to investigate what happens if the teaching of body functions starts in another end compare to the traditional way in textbooks. Instead of reading about the different organs and organ systems the teaching could profit from starting in a dilemma. The dilemma could be to discuss what happens when you drink a glass of water, and discuss with the students the following processes – also including the cells. One can introduce discussions of imaginary paths for the water molecules through all involved processes in the body. It would be of interest to analyse students' understanding of the connections between different organ systems in the body after them having taken part in teaching with this perspective on the processes in the human body.

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APPENDICES

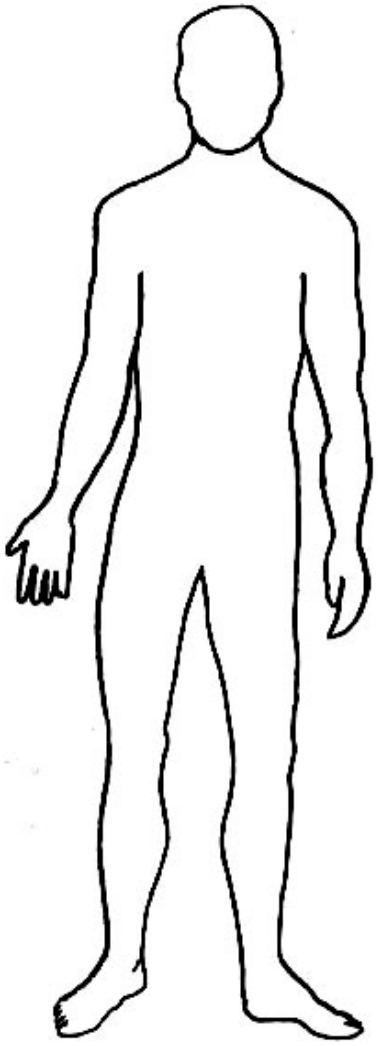
APPENDIX A:

VERBATIM TRANSLATION OF SWEDISH INSTRUMENTS.

Name:_____

Class:_____

Describe as carefully as you can (draw and write) what happens in the body when you are eating a sandwich



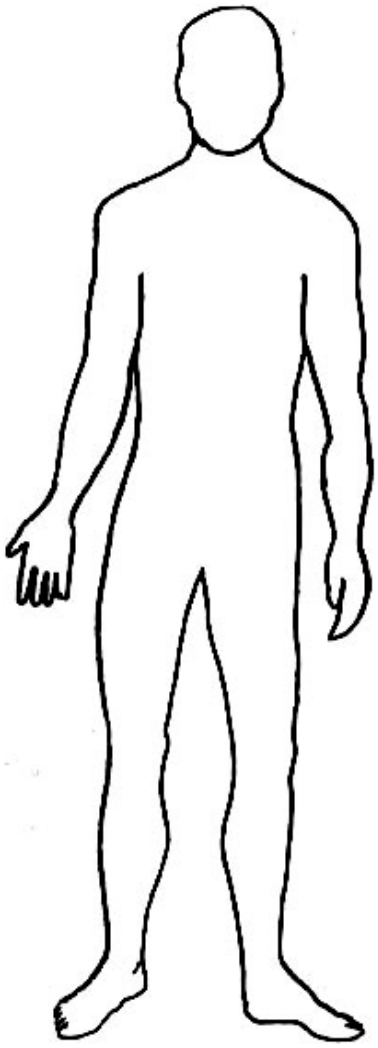
What (kind of) food makes you feel good to eat?

What happens in the body if you skip a meal you usually have?

Name:_____

Class:_____

Describe as carefully as you can (draw and write) what happens in the body when you drink water

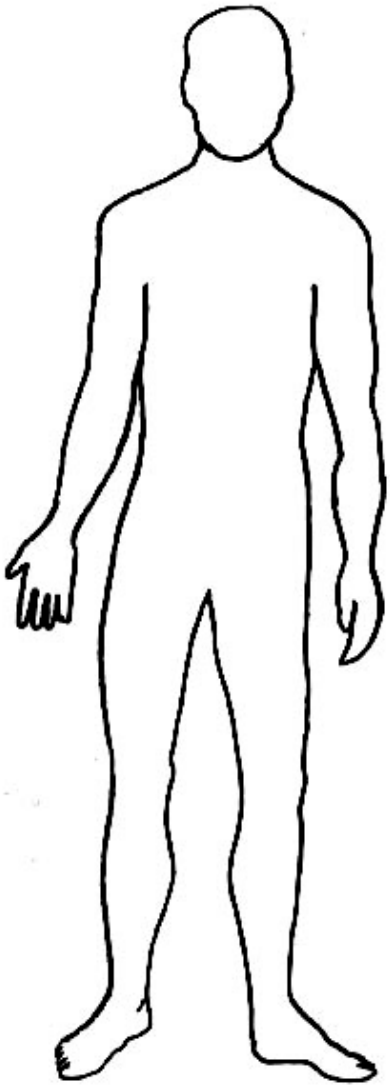


Why is it important to drink water?

Name:_____

Class:_____

Describe as carefully as you can (draw and write) what happens in the body when you eat a painkiller (for example Alvedon)



If you are in pain, are there any alternatives to taking a painkiller to alleviate the pain?

Name:_____

Class:_____

Choose one of the alternatives

1. What is the main function of the kidney?

- ☐ To produce antibodies against illness
- ☐ To decompose food
- ☐ To circulate the blood
- ☐ To produce red blood cells
- ☐ To clean the blood from waste products

2. If you eat 100 grams of any of these foods, which would give the body the largest amount of protein?

- ☐ Potatoes
- ☐ Apples
- ☐ Rice
- ☐ Bread
- ☐ Chicken

3. What is the main function of sweating?

- ☐ To keep the body temperature constant
- ☐ To keep the skin moist
- ☐ To protect you from catching a cold
- ☐ To get rid of surplus salt in the body
- ☐ To get rid of surplus water in the body

Please turn over.

4. The blood has many functions in the human body. Which function does the blood **not** have?

- ☐ To break down food
- ☐ To protect the body from illness
- ☐ To transport nutritious substance to the cells
- ☐ To transport waste from the cells
- ☐ To transport oxygen to different parts of the body

5. What is the MOST IMPORTANT reason for including fruits and vegetables in a diet?

- ☐ They have high water content.
- ☐ They are the best sources of protein.
- ☐ They are rich in minerals and vitamins.
- ☐ They are the best sources of carbohydrates

6. From where have you got your knowledge about the body and health?
(Here you can choose more than one alternative)

- ☐ School If yes, in what subjects: _____
- ☐ Parents
- ☐ Friends
- ☐ Newspapers
- ☐ Television
- ☐ Internet
- ☐ Radio
- ☐ Other:_____