Chapter 17
Understanding the Pathway of Water Through the Body: Student Teachers' Knowledge and Essential Concepts for Future Pupils

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17.1 Introduction

Knowledge about organs and organ systems is taught in schools all over the world. In Sweden, where the present study took place, this focus on the human body forms a large part of the curriculum and the content in textbooks at all stages of the mandatory schools (Skolverket, 2018), as well as in some of the upper secondary school courses (Skolverket, 2013). However, in most countries (if not all), much of the biology curricula focuses on students' understanding of the function of the human body.

By the time students reach secondary or upper secondary school, most have learned about the body on several occasions during their school years. Examples include the three curricula in the mandatory schools (grades 9–10): in the National Curriculum in England (2014, 2015), the curriculum for Secondary Level I—Biology in Baden-Württemberg, Germany (Bildungspläne Baden-Württemberg, 2016), and the National Agency for Education in Sweden (Skolverket, 2013, 2018). All three curricula aim to ensure that the students receive knowledge about the circulation system, the lungs and respiratory system, the excretory system, the function of the cells, and so on. However, in Sweden, biology can be studied as a standalone subject at upper secondary schools and as part of the more general subject of science. The general science subject includes biology, chemistry, physics, and geology, and the course is required by all upper secondary students in Sweden. The prospective teachers who aim to teach grades 1–6, need at least two courses in general science. The second science course and the biology course include a unit with a focus on the human body (Skolverket, 2013).

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In the science courses at the university, one aim is to gain knowledge of the organ systems and to set the subject-matter in an education setting so that the students gain the skills they need to teach the subject-matter to pupils. It is a challenge for adults to describe what happens to water from the time a person drinks it until they urinate. The problem is that the description of the process itself, even at a macro level, requires that the person understands the connections between several organ systems (for example, digestive, circulatory, and excretory systems) (Granklint Enochson, 2024).

17.2 Background

17.2.1 General Knowledge of Organs and Organ Systems

People cannot see what is happening inside the body, which makes it difficult to comprehend the processes that take place in it. One example is the connection between the input (via the mouth) and the output (urine) of the excretory system; what happens in between is not entirely clear. For instance, how sweating is linked to water excretion is seldom discussed in everyday conversations. Biology textbooks use the term "organ system", but what do we know about people's knowledge of organ systems?

Preschool children often draw individual organs without showing the connections between them (e.g. Cuthbert, 2000). The older the child becomes, the more he or she should understand how organs are comprised as systems that can be interpreted as organ systems (e.g., Andersson et al., 2020; Dempster & Stears, 2014; Garcia-Barrosa et al., 2011). The organ system that most people are familiar with is the digestive system, but what this knowledge means in this context requires explanation from a macro perspective.

The digestive system, with its input and output (that is, food enters through the mouth and comes out in the form of feces), is not particularly problematic to understand. The explanation that we ingest food through the mouth, then it goes to the throat, down to the stomach, and then further on to the intestinal system, is also relatively well-known from middle school (e.g. Carvalho et al., 2004; Garcia-Barrosa et al., 2011; Granklint Enochson & Redfors, 2012; Óskarsdóttir et al., 2011; Reiss et al., 2002; Tunnicliffe, 2004). Explaining the digestive system at this level includes being able to define the path of food at the macro level. However, it is much more difficult to connect cells or cell structures to reasoning about the digestive and circulatory systems (e.g., Granklint Enochson & Redfors, 2012).

17.2.2 The Body—Connections Between Organ Systems

In relation to explaining the "tube" in the digestive system, a more complex explanatory model is required to describe what happens in the body when a person drinks water (that is, from the moment of drinking a glass of water to when the water leaves the body as urine). To explain this process at the macro level, it is necessary to use an explanation that refers to at least three organ systems (the digestive system, the circulatory system, and the excretory system). Several studies have shown that it is difficult for students (and adults) to describe which systems are involved and how they are interconnected (Canlas & Molino-Magtolis, 2024; Carvalho et al., 2004; Clément, 2003; Cuthbert, 2000; Manokore & Reiss, 2003; Prokop et al., 2009).

One reason for this difficulty involves the student teachers' struggle to link the various organizational levels (Assaraf et al., 2013; Hmelo-Silver et al., 2008). Clément (2003) also pointed out some of the causes of the difficulties—one of which is ontological. In everyday speech, we rarely talk of intestinal walls as being permeable. Understanding the permeability in the connection between the different organ systems in the body is a prerequisite for explaining the processes of nutrients and water moving from one organ system to another (Clément, 2003). It is also significant that understanding the breaking down of nutrients is required to understand the transition between the gut and the circulatory system (Jahic Pettersson et al., 2021). A further problem with understanding the pathway of water through the body is that everyday perceptions about the process are based on explanatory models that are not scientifically based; for example, descriptions that contain explanatory models that describe tubes from the throat linking directly down to the kidneys (Clément, 2003; Granklint Enochson & Redfors, 2012) or that the water makes its way past the lungs before reaching the stomach (Granklint Enochson et al., 2015). It is relatively common for people to hold scientific misconceptions. Among ninth graders (Granklint Enochson & Redfors, 2012), a quarter of the participants exhibited various types of misconceptions, while in another study (Granklint Enochson, 2024) involving adults (pre-service teachers in preschool), nearly half held such scientifically unverified beliefs. Two dominant misconceptions emerged in these studies: one involves the idea of a direct tube from the mouth to the kidneys, as described above, while the other suggests that water is transported from the stomach directly into the body—sometimes with a connection to the circulatory system, but more often simply diffusing into the body. However, additional types of misconceptions exist. In a study conducted in South Africa, approximately half of the ninth-grade students assumed that water must pass through the lungs before reaching the stomach (Granklint Enochson et al., 2015). Notably, the students in this study were able to articulate their reasoning, with several stating that "water purifies the body" as an explanation for why they believed that water must pass through the lungs. Another finding in Granklint Enochson and Redfors (2012) was that the students with non-scientific descriptions also had difficulties explaining the function of the kidney.

Research has shown how students and adults use several differing non-scientific explanatory models to explain what happens to water in the body. Other studies show that the transitions between organ systems make understanding problematic, particularly because the explanation requires knowledge of the invisible (that is, entities and activities at the micro level). The present study focuses on the knowledge the pre-service student teachers bring with them into the science course at the university about the pathway of water through the body and what knowledge the students think they should teach to the pupils. In addition, this study examines what the students expect will be challenging to teach about the water pathway.

17.2.3 Learning About Organs and Organ Systems

Learning Science

According to Ausubel (1968), knowledge is built upon by adding further knowledge. In other words, knowledge that we have previously acquired is the basis for generating new knowledge. This can be linked to how pre-service student were taught about the human body in upper secondary school, specifically whether the instruction focused on individual organs or organ systems. Ultimately, this has implications for how universities address and build upon students' prior knowledge. However, understanding the fundamental functions of the body can be viewed as a characteristic of scientific literacy, particularly as it is stipulated in the school's curriculum.

Citizens need to be scientifically literate in order to be able to encounter, for example, the news. However, scientific literacy comes with understanding the epistemology of science (Glaze, 2018) (for example, how we know about the processes that happen in the body). Nevertheless, understanding about the body could also be explained by misconceptions, which may be related to how the science knowledge that the students are taught in school does not harmonize with ideas that are prevalent in their everyday culture (Aikenhead, 2005; Lemke, 2000; Phelan et al., 1991). It is also possible that the students have not been introduced to the topic in a way that allows them to develop a scientific approach to the content (Vygotsky, 1934/1986). Learning is also connected to interest in the subject. Potvin and Hasni (2014) showed that the problem of low student interest persists; interest declines the longer the students have been in primary school, with a large gap between what students want to know and what subject content they are taught.

Knowledge Required to be a Teacher

For effective teaching, three aspects are important: the teachers' own knowledge of the subject, the teachers' knowledge of the students, and the context in which the learning takes place (Shulman, 1990). How a teacher chooses to use their subject knowledge and the teacher's pedagogical awareness are also crucial for the students' knowledge development (e.g., Park & Oliver, 2008; Shulman, 1990). Pedagogical content knowledge (PCK) is a crucial aspect of effective teaching that encompasses a teacher's knowledge of instructional strategies, students' understanding, assessment, the curriculum, and teaching orientation (Tuithof, 2017; Williams & Lockle, 2012). It is a unique blend of content and pedagogical knowledge that develops over time and through experience (Van Driel & Berry, 2010). The alignment of a teacher's goals and beliefs with the curriculum goals is a key determinant of their PCK (Tuithof, 2017). PCK is seen as the integration of pedagogy and content and is essential for elevating teaching to a professional status (Shing et al., 2015).

17.3 Aim and Research Questions

The aim of this study is to investigate pre-service teachers' ideas about organs and organ systems, in particular the pathway of water through the body. The focus lies on pre-service teachers who will teach grades 1–3 and 4–6. Furthermore, the study examines what pre-service teachers perceive as challenges in teaching this subject-matter to their students in the future.

Research Questions (RQ):

What ideas do pre-service student teachers have about organs and organ systems, specifically regarding the pathway of water through the body?
What ideas do pre-service student teachers have about the function of water in the body?
What do pre-service student teachers perceive as challenges in future teaching situations?

17.4 Research Design and Method

Sample

The sample of this study consisted of 48 pre-service teachers. All participants were students enrolled at a Swedish university and in pursuit of a Master of Arts degree in primary education, either at the level of pre-school, school grades 0–3 (0 is pre-school class for children aged six years), or school grades 4–6. One-third of the participants were male (see Table 17.1). All the students were in the third year of a four-year course. The data were collected on their first day of the science course, with none of the students having previously taken university-level biology courses. What makes this particular teacher education unique compared to other Swedish universities is that, from the outset, all the students chose to enter a degree program with a focus on science education in one of the semesters. The students who would teach grades 0–3 had already had four weeks of teaching practice in schools, which was part of the course plan for the semester.

Table 17.1 The student teacher participants in the study

Pre-service teachers with the aim to teach in:	Number of participants	Female/Male
Grades 0–3	25	20 female, 5 male
Grades 4–6	23	13 female, 10 male

Data Collection

For this study, the data source was a questionnaire with two parts. In the first part, the students were asked to draw and write. For the drawing, an outline of a non-gender-specific human body figure was provided to them. The students were instructed to use the outline for drawing the pathway of water through the body. The figure used in this study had been used in several other studies before (e.g., Dempster & Stears, 2014; Granklint Enochson, 2024 used a similar figure) and was originally created by Pernilla Granklint Enochson in 2008 (Granklint Enochson, Helldén & Lindahl, 2008) (see Table 17.2). In the second part of the questionnaire, three open-ended questions were presented. These questions explored students' beliefs regarding the necessity of drinking water, as well as their expectations for future teaching in this subject.

- Why is it important to drink water?
- What do you expect your pupils to learn about water in the human body?
- What difficulties/limitations may arise when teaching about water in the human body, i.e., what problems might occur in the teaching situation?

And finally, a questionnaire with multiple-choice questions was used to examine whether or not there is a connection between the students' knowledge of the pathway of water through the body and the function of the kidneys. The following is an example of a multiple-choice question used:

What is the main function of the kidneys? (Put a cross)

- To produce antibodies against diseases
- To break down food
- To circulate blood
- To produce red blood cells
- To purify the blood of waste products.

Data Analysis

Teacher students' drawings and writings using the outline of the non-gender-specific human body were categorized according to coding instructions, as described by Granklint Enochson and Redfors (2012) and Granklint Enochson et al. (2015). The analysis is content-based and focuses on the level of complexity in the students' explanations, in terms of connecting different organ systems. The pre-service teachers' sketches and writings were analyzed according to the following categories:

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 are missing
D. Descriptions following a scientific explanatory model—important parts included (at least three organ systems—digestive, circulation, excretion)

The analysis of the open-ended followed a more classic content analysis, which focused on how pre-service teachers expressed their knowledge in the text they wrote.

Zhang and Wildemuth (2017) outlined an eight-step process for conducting content analysis: preparing data, defining the focus of analysis, identifying categories, testing categories, coding the data, assessing the coding reliability, drawing conclusions, and reporting the findings. The category system in this study was developed following a similar process as described by Zhang and Wildemuth (2017). The data collection in this study utilized the same template and categorization system as those employed in previous research (e.g., Granklint Enochson & Redfors, 2012). Nevertheless, all templates were tested by university colleagues during a seminar to ensure the accuracy of the categorization of the figures. There was disagreement about only one template, which was ultimately placed in Category A instead of Category B.

17.5 Results

What ideas do pre-service student teachers have about organs and organ systems, specifically regarding the pathway of water through the body?

The results from the students' categorization of the drawings and writings on the template showed that two of the categories each accounted for one-third of the answers. These two categories were Category B (non-scientific descriptions based on alternative ideas of the organ system) and Category C (descriptions following a scientific explanatory model—important parts were missing) (see Table 17.2). A noteworthy aspect of Category B is that nearly all the student teachers had the understanding that water is distributed to other parts of the body through the stomach, thus lacking the understanding that water uptake takes place in the intestines. Also, according to Category C, either the circulation system or the kidneys were missing (see Table 17.2).

The open-ended question "*Why is it important to drink water?*"

This question has been examined from two perspectives: first, the pre-service teachers' understanding of the necessity of water consumption, and second, the extent to which their beliefs are associated with their knowledge of organ systems. The student teachers' responses to the open-ended question indicated that no direct link could be found between their knowledge of the water pathway and their understanding of the importance of drinking water. However, three different categories of answers to the question of why it is important to drink water were found. Eleven

Table 17.2 The categorization of the student teachers' knowledge

Pre-service teachers with the aim to teach in:	Category A	B	C	D	Sum
Examples of drawings					
Grades 0–3	4	7	7	7	25
Grade 4–6	5	7	9	2	23
In total	9 (19%)	14 (29%)	16 (33%)	9 (19%)	48 (100%)

pre-service student teachers gave answers that added nothing beyond the question (for example, it is important to drink) or the students wrote very generally about water (for example, water is good for the body). Twenty-one students answered with sentences like "filling up with water" (hydration). Twelve of the 48 students gave a more scientific explanation concerning water as carrier of nutrients (most of them) or as a regulator of temperature (Table 17.3). Three of the students had the misconception that water was part of the process of breaking down nutrients. One student did not give an answer.

Multiple-choice question "*What is the main function of the kidneys?*"

Regarding the multiple-choice question, "What is the main function of the kidneys?", 23 of the pre-service student teachers who intended to teach grade 4–6 and 19 pre-service student teachers out of 25 who intended to teach grade 0–3 selected the answer "to purify the blood of waste products". The percentage of students who gave such

Table 17.3 Some of the student teachers' knowledge about *Why is it important to drink water*

Water breaks down nutrients	The function of water in the body, such as transportation of nutrients (or regulation of temperature)
A: 0 B: 1 student C: 1 student D: 1 student In total, 3 students	A: 2 students B: 4 students C: 4 students D: 2 students In total, 12 students

an answer was equally distributed across categories A to D used to classify drawings and texts about the pathway of water through the body. This suggests that all students were aware that the kidneys filter waste products from the blood.

The open-ended question: What challenges may arise when teaching about the pathway of water through the human body, i.e., what problems might occur in the teaching situation?

When the pre-service student teachers elaborated on difficulties and challenges of teaching about the pathway of water through the body, there were three dominating themes. The first was their own level of knowledge. A common response—"Much more than I know now. Specifically, what processes occur in the body when the body takes in fluid"—came from a student who had a knowledge level of Category C (descriptions following a scientific explanatory model—important parts were missing). The students were aware of their lack of knowledge and hoped to gain more knowledge in the science course in order to teach the subject-matter to primary school students in the future. The second theme was related to the characteristics of water and the following statements: "How important water is for humans and that water cannot be compared to other liquids such as soft drinks, juices, coffee and tea" and "What water contains". This type of statement indicates that the pre-service students believed their own students would face challenges in understanding that the water in soft drinks is the same as tap water. The third theme was about "The benefit of water for hydration".

Furthermore, the students responded to the question about difficulties and challenges of teaching the subject-matter to primary school students in the future at a rather general level. More specifically, most pre-service student teachers indicated general pedagogic reasons such as pupils' behavior, time for preparation, and so on. Quite a few were worried about their ability to teach. However, only a few students (two students in 0–3 and four students in F-6) indicated disinterest in the subject as a challenge.

17.6 Discussion and Conclusion

A primary objective of this study was to examine the prior knowledge that pre-service student teachers, who will teach primary school students (grades 1–6), bring to university-level science courses. This cohort is particularly significant, as these individuals will be responsible for introducing pupils to formal science education. Understanding their conceptual approaches and scientific knowledge is therefore essential.

In comparison to previous research, the explanations provided by students in this study were less scientifically accurate than those of Grade 9 students in compulsory school (Granklint Enochson & Redfors, 2012) but more scientific than those observed in a study involving pre-service student teachers with an average age of 37, who were presumed to have prior experience teaching in preschool settings (Granklint Enochson, 2024). Notably, the students in the present study—having completed upper secondary school more recently than those in Granklint Enochson (2024)—did not exhibit the common misconception, documented in earlier research, of conceptualizing a direct tube from the mouth to the kidneys. However, a different type of misconception emerged in their drawings, which depicted water traveling from the stomach into the circulatory system rather than passing through the intestines. Despite these findings, no clear relationship was identified between students' understanding of the pathway of water through the body and their knowledge of kidney function or their awareness of the importance of water consumption for pupils. This contrasts with previous studies that have indicated such connections (e.g., Granklint Enochson & Redfors, 2012). It seems that students have not sufficiently problematized the water pathway or the diverse functions of water in the body in general, during their previous education. Some even mistakenly perceive water as a nutrient in itself. This gap in knowledge may stem from either inadequate exposure to the subject-matter (Vygotsky, 1934/1986) or a lack of interest in science during their schooling (Potvin & Hasni, 2014). Several studies have highlighted that students often show less interest in science compared to other school subjects (e.g., Potvin & Hasni, 2014) and that teachers play a crucial role in shaping students' engagement with scientific topics (e.g., Chen et al., 2024).

Given this, it is essential for university educators to assess and address the prior knowledge of pre-service teachers, ensuring they understand the connections between different organ systems and the interconnections linking them, as highlighted by Clément (2003). Additionally, university instructors must recognize and address common misconceptions among students, as these can significantly impact their future teaching practices. A well-structured teacher education program should not only provide a robust understanding of human biology at both the organ and system levels but also equip future educators with pedagogical strategies to address student misconceptions effectively (e.g., Park & Oliver, 2008; Shulman, 1990). Interestingly, the students in this study did not identify a lack of interest as a potential challenge in their future teaching. However, it remains crucial for educators to establish a baseline understanding of students' prior knowledge to facilitate the construction of new scientific concepts (Ausubel, 1968). Given that most participants began their academic studies within five years of completing upper secondary school, their secondary education experiences can be considered relatively recent. This study may therefore have a direct impact on how teacher education programs address the misconceptions and prior knowledge that students bring into their university studies.

The limitations of this study include the relatively small sample size and the fact that all participating students were admitted to the university in the same year, which may have influenced the results. The dropout rate among students was minimal and was limited to those who were absent for legitimate reasons. All students who were present at the university on the day of the study voluntarily chose to participate. Furthermore, the author of this article did not teach the participating group about human biology either before or after the data collection, ensuring that the responses were not influenced by a potential assessment situation.

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