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USING CONCEPT MAPPING AS ASSESSMENT TOOL IN SCHOOL BIOLOGY

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Abstract. The science topic of human body systems is important for students academically and for understanding and maintaining a healthy lifestyle. Teaching middle school students about the digestive and excretory system can be a challenge for a teacher when she/he wants to overcome rote learning of facts without a deeper understanding. It is suggested (e.g Ulerick, 2000) to use and learn some alternative ways from textbooks. Graphic strategies, such as concept mapping and related techniques, can assist students in visualizing how key ideas are related to each other. This paper examined the research question: how concept mapping as an assessment tool can improve the instructional practices and can be used for identifying middle school students' misunderstandings about the human digestive and excretory system. For assessment the topics of human digestive and excretory system construction of concept maps was used. An analysis of the 29 concept maps created by the 9th grade students in biology lesson revealed that student demonstrate an understanding about focus question: how the nutrients are absorbed into blood, wastes leave the body and urine is formed by sixteen central concepts. This study reports that students' basic knowledge about their internal body parts is on expected level. Students' terminology for the identification of the organs' functions after studying this topic were quite good. In creating the maps, student clarified concepts and became gradually aware about interconnections.

1 Introduction

Science education aims far more than the ability to recall information of facts and names. The studies about students` learning problems in science reveal that they have a large number of misconceptions even after receiving formal instruction. To encourage meaningful learning and to minimize the students' alternative ideas about the explanation of complex body processes, teachers especially should recognize the importance of assessment. Teachers can assess what students have learned at the end of the lesson, using different techniques such as writing, concept tests, concept map etc.

2 Theoretical background

Studies have showed that students have problems in understanding key topics of biology such as internal organs, organ systems and processes of their own bodies (e.g Bahar, Johnstone & Hansell, 1999). Toyoma (2000) have evaluated young children awareness of biological transformations associated with eating and breathing and showed that young children seldom refer to biological transformation. Results from an international study (Reiss et al, 2002) about 15 year-olds students´ (from 11 different countries) understanding of different organ systems show that the generally best known organs belong to the digestive system, the gaseous exchange system and the skeletal system. Student had better knowledge of their internal organs, most of them revealed little understanding of their organ system. Tunnicliffe (2004) found that 9-10 year old students had greater difficulties in understanding the excretory systems than the digestive. In this study concept mapping has been used as a tool to identify middle school students' misconceptions about the human digestive and excretory system.

A variety of methods have been used to examine students' understandings and to detect alternative conceptions in science education and in biology such as multiple choice items (e.g. Odom, 1995), construction of concept maps (e.g. Novak & Gowin, 1984), using analogy in teaching (e.g. Rule & Furletti, 2004), using the drawing (Özsevgec, 2007), and so on.

School is mentioned as a source of knowledge by secondary pupils rather than ones of primary age, and then not very often (Tunnicliffe & Reiss, 2000). In Estonia the science is taught as an integrated subject from the 1th to 7th grade and from the 7th grade biology is taught as a separate subject. The basis for the study of the human muscular, skeletal, digestive, excretory, respiratory and circulatory, reproduction, nervous, endocrine, immune, systems is currently presented in Estonian National Curriculum (Estonian Government, 2002). Within the primary science syllabus, the subject matter of digestion, respiration is introduced progressively from grade 2th to grade 4th. In grade 2th, pupils are introduced to the concept that livings need air, water and food to survive; they are taught life cycles of plants and animals. Each of systems (skeletal, digestive, circulatory, respiratory, excretory and nervous) and their organs' function and locations are taught simply at grade 4th. Different aspects with greater depth of understanding are covered in human anatomy lessons in grade 9th. According to the National Curriculum the students should have knowledge about the following content at the end of the 9th grade (aged 15/16) students should: be able to identify human organs and organ systems and explain the relations

between their structure and function; follow the principles of a healthy and sustainable way of life; put the knowledge acquired in biology lessons into practice and to relate it with knowledge acquired from other sources, plan and carry out simple biological experiments; make observations, record the results and present them…“ (Estonian Government, 2002). In Estonian lessons the human organs are taught individually, but it is emphasized that these organs are parts of systems and then have been going into more detail.
A more traditional approach to teaching is practiced in Estonia. Students are expected to master an understanding of basic concepts, content, and vocabulary in biology. Previous study has showed, that student do not do so much laboratory investigation and experience applying scientific methodology (Henno & Reiska 2007). The relatively strong “academism” has its positive side and perhaps is one of the possible factors that explains the Estonian students' success in TIMSS 2003 and in PISA 2006. In TIMSS 2003 according to mean scores Estonia ranked sixth in life science and in PISA 2006 fifth in science and on the basis of the mean score on the living systems' scale of scientific knowledge, third after Finland and Hong Kong – China. In TIMSS 2003 it was revealed, that on average 80 % of Estonian students taught by teachers reported using a textbook as primary basis of their lessons (Martin *et al.,* 2004: 308).

The science topic of human body systems is important for students academically and for understanding and maintaining a healthy lifestyle. Teaching middle school students about the digestive and excretory system can be a challenge for a teacher when s/he wants to overcome rote learning of facts without a deeper understanding. It is crucial to realize that Estonian current biology textbooks have some shortcomings and cannot be relied upon to provide the inquiry instruction for biology at the middle school level. Teachers must contextualize the role of textbooks within effective instructional practices. The students use their teachers’ terminologies and teachers should pay attention their words used in their lessons.

Acknowledging the difficulties in learning from textbooks, Ulerick (2000) have suggested some alternative ways to use and learn from textbooks. She suggests using graphic strategies, such as concept mapping and related techniques, to assist students in visualizing how key ideas are related to each other. Given the particular weakness of textbooks in promoting the connections among ideas, this seems a particularly important strategy.
In Estonia homework is an important part of teachers` instructional strategy. Homework assignments can reinforce classroom learning and encourage students to extend their understanding of the biology. In the end of concrete themes/courses the students have summative science tests.

Assessment is an integral part of teaching and learning, providing feedback on progress through the assessment period to both learners and teachers. Concept map can be used for showing the topics/contents, in introducing a topic to the students and for evaluation or assessment (Rice, Ryan & Samson, 1998).

This paper examined the research question: how concept mapping as an assessment tool can improve the instructional practices and can be used for identifying middle school students' misunderstandings about the human digestive and excretory system?

3 Methods

In this research concept mapping has been used as a tool to collect the data and as a student assessment tool. Data for this study include 29 middle-school students from Science High School – constructed concept maps showing how student integrate information about the human digestive and excretory system. The sample included the students in the 2006/2007 study year. 9th grade students were taught during one study year (70 week) and assessed normally by written tests. The types of test formats for biology were mostly constructed-response biology tests. On average the students had a biology tests about once a month. For assessment the topics of human digestive and excretory system was used the construction of concept maps.

Concept maps were created using CmapTools program from the Institute for Human and Machine Cognition. At first, students were explained in the subject classroom about the bases of concept maps. After the classroom instructions the students constructed maps for the first time in their practice about human nervous system using the biology textbooks (biology textbook published by publisher AVITA in Estonia) in computer class.
After two weeks of studying (four lessons) the digestive and excretory topics and monitoring the homework assignments from textbooks the summative assessment was taken place in computer class, where during 45 minutes students mapped individually their understanding about interaction of the digestive and excretory system by heart, by using the software CmapTools. The focus question for concept mapping was: *how the nutrients are absorbed into blood, wastes leave the body and urine is formed.*

This report describes a quantitative content analysis of 29 students` concept maps. For this survey the 9th grade biology textbook texts about the digestive and excretory topics were scanned and a list of concepts and meaningful propositions was compiled. 60 new full word/ concept names and 58 new semantic propositions connected with the topics of the digestive and excretory system were accounted in the biology textbook material for students.

For this study, a quantitative approach is adopted. Students' concept maps are assessed mainly, using counting, in terms of the concept names, linking words used in between the concepts and valid and invalid propositions, list of concepts and meaningful propositions from the biology textbook. Valid propositions are formed by connecting valid nodes with suitable linking words. The content of the concept maps is summarized in Table 1.

Table 1. Number of contents, propositions and cross-links and students´ mean score of biology test of study year.

No of student	Mean score of biology tests	No of invalid concepts	No of correct concepts	No of invalid prop.	No of valid prop. according to textbook	Number of valid propositions	Cross-links	No of links of central concept	Central concepts (with number of links)
1	4,25	0	15	0	9	20	0	3	blood (3), kidneys (3)
2	4,25	1	17	1	10	20	0	5	food (5), excretory system (4), kidneys (4)
3	4,75	0	26	0	19	32	0	3	focus question (3)
4	5	0	29	1	16	30	1	5	wastes (5), digestion (5)
5	3,75	0	21	0	15	24	0	4	wastes (4)
6	5	0	47	0	29	37	0	5	blood (5)
7	5	0	25	0	14	24	0	5	wastes (5), kidneys (4)
8	5	1	31	1	20	22	1	7	digestive system (7), wastes (5)
9	4,5	2	14	0	10	18	0	4	small intestine (4), blood (3), stomach (3)
10	4,5	0	14	0	6	12	1	4	bloodstream (4), kidneys (3), renal corpuscles (3)
11	4,5	1	23	0	10	27	0	6	nutrients (6), excretory system (5)
12	5	0	30	0	20	28	0	4	small intestine (4)
13	4,25	0	22	0	13	18	1	5	wastes (5)
14	4,75	0	19	0	9	18	0	5	wastes, urine (3), small intestine (3)
15	5	0	14	1	9	21	0	4	small intestine (4)
16	4,75	0	15	0	9	17	1	4	nutrients (4), renal corpuscles (4)
17	5	0	13	1	9	17	0	4	blood (4), prourine (3)
18	4,25	0	9	0	6	12	0	3	focus question (3)
19	3,75	3	20	0	9	18	0	7	digestive system (7), kidneys (4), wastes (5)
20	5	1	26	1	15	21	0	4	nutrients (4)
21	4	1	8	0	7	8	0	2	0
22	4,25	0	14	0	8	15	1	4	blood (4), kidneys (3), nutrients (3)
23	4,25	1	23	2	12	25	0	4	nutrients (4), kidneys (4)
24	5	1	19	2	15	22	1	4	nutrients (4)
25	4,5	0	19	2	14	16	0	4	focus question (4)
26	5	0	16	2	9	22	1	4	excretory system (4), tubular system (4)
27	4,25	1	10	1	9	12	0	3	focus question (3)
28	4,25	0	11	2	6	12	0	2	focus question (2)
29	4,5	0	23	0	12	28	0	5	food (5), wastes (5), kidneys (5)

In this study the mean of test scores (the study year) were compared with the number of contents, propositions and cross-links in students´ created concept maps. The correlation coefficient between these was measured.

4 Results

Concept mapping was used in the biology classroom to assess students' conceptual frameworks by analyzing the ways students organize and present knowledge. It was intended to determine whether the use of concept maps in the classroom as an assessment tool can identify and address specific misconceptions.
An analysis of the 29 concept maps created by the 9th grade students in biology lesson revealed that students demonstrate an understanding about focus question: *how the nutrients are absorbed into blood, wastes leave the body and urine is formed* by sixteen central concepts (blood, bloodstream, digestion, digestive system, excretory system, food, kidneys, nutrients, renal corpuscles, small intestine, stomach, theme, tubular system, wastes, urine, prourine). The most popular concepts were: *blood* and *focus question* (was used as central concept by five students), kidneys and wastes (was used as central concept by eight students) and *small intestine* was used as central concept by five students).

The all concept maps were structured by hierarchically. An example of the best constructed concept map is presented on figure 1 and the purest is on figure 3. It seems at first that the best map has several cross-links, but by restructuring the same map by the linear way we can not find any cross-links (figure 2).

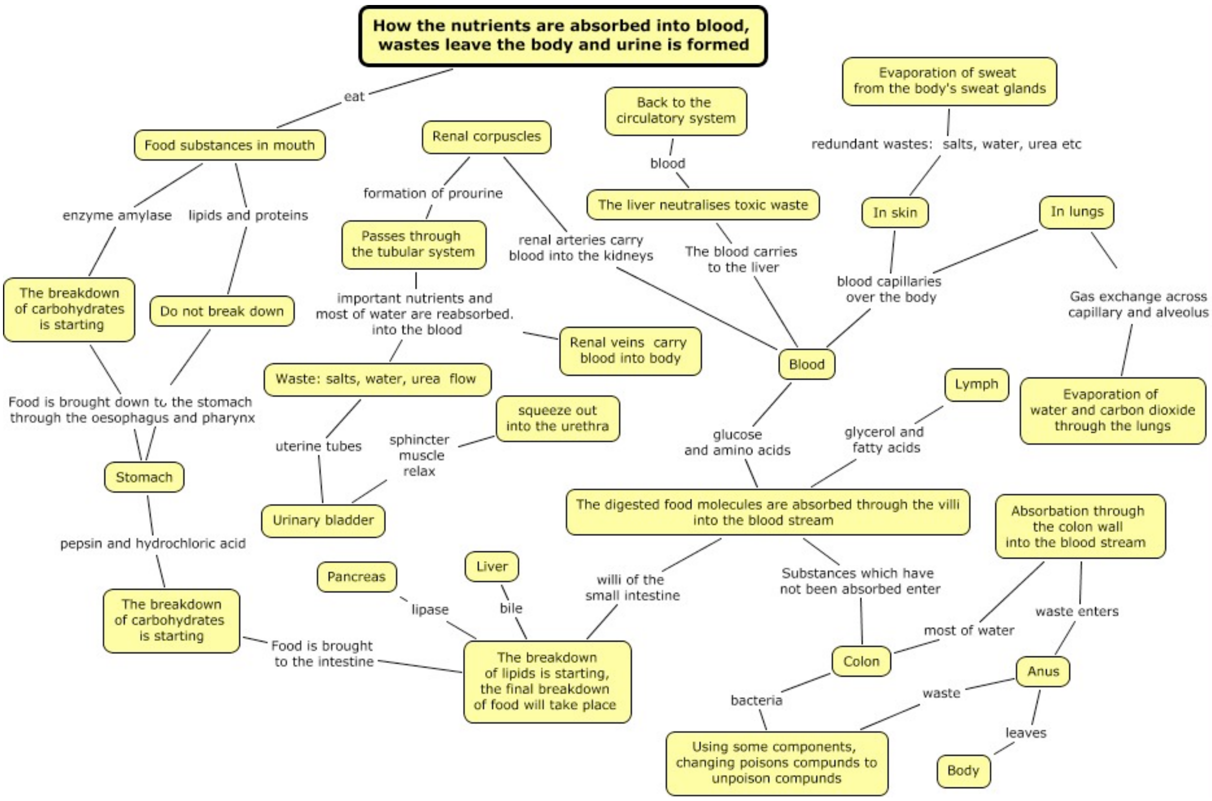

Figure 1. An example of a student: best constructed concept map to show how the nutrients are absorbed into blood, wastes leave the body and urine is formed

The digestive and excretory topics were taught to the students and student created maps do not reflect the previous deficiencies. Students have gained broader knowledge and were able to relate new concepts to more general ones. Students’ daily life experiences may cause some alternative conceptions. There were some typical invalid propositions done by students. Students used “the food is absorbed into the blood” instead of “the digested food molecules are absorbed into the blood”. They used “excretion of air” instead of “elimination of carbon dioxide and water”. Some students also ascribed to the stomach, *digesting of proteins and carbohydrate,* some believe that fatty acids are absorbed through the villi into the blood stream.

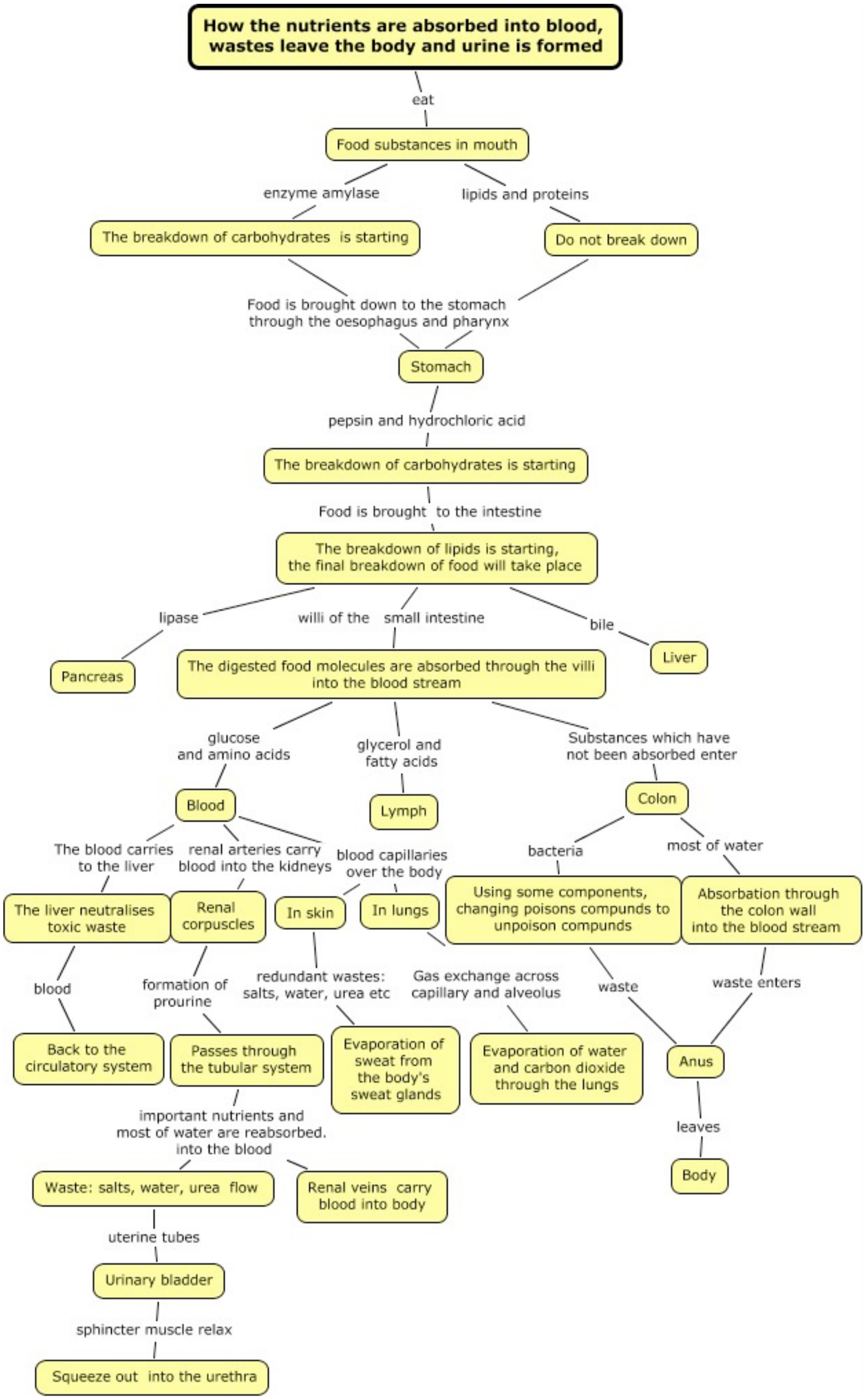

Figure 2. Example of the best concept map reconstructed by linear way

The correlation coefficient was measured between the mean of test scores (the study year) with the number of contents, propositions and cross-links in students´ created concept maps. Table 2 shows the results.

Table 2. Correlation coefficients

Correlation coefficient between	Correlation coefficient
Mean score of biology tests and number of invalid concepts names	-0,34
Mean score of biology tests and number of correct concepts names	0,44
Mean score of biology tests and number of invalid propositions	0,23
Mean score of biology tests and number of valid propositions according to textbook	0,46
Mean score of biology tests and number of valid propositions	0,45
Mean score of biology tests and number of cross-links	0,25
Mean score of biology tests and number of links of central concept	0,16

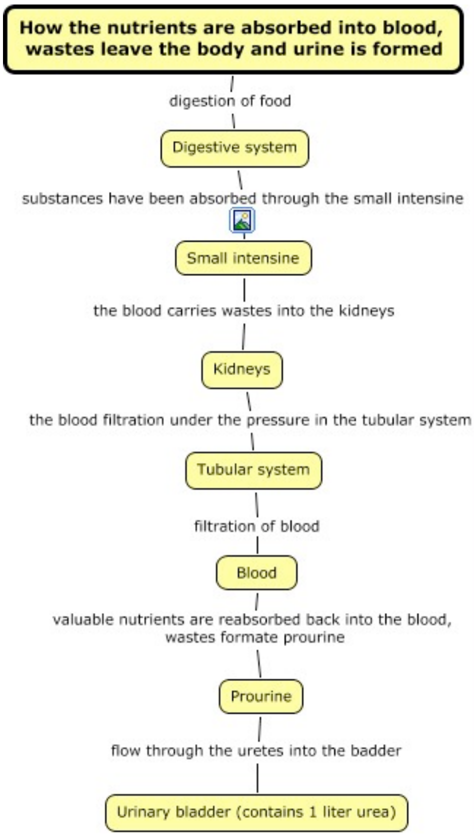

Figure 3. Example of the purest concept map

5 Summary

This study reports that students' basic knowledge about their internal body parts is on expected level. Students' terminology for the identification of the organs' functions after studying this topic were quite good. In creating the maps, students clarified concepts and became gradually aware about interconnections.

Generally, students demonstrated their ability to draw interconnections between digestive and excretory systems.

Teachers must be informed about students' understandings and they should design their science lessons according to these points. Teachers also should be informed about different teaching methods depending on the students' active learning.

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