Concept Maps: Making Learning Meaningful
Proc. of Fourth Int. Conference on Concept Mapping
Viña del Mar, Chile, 2010

DIFFICULTY OF TEXTS IN UPPER-SECONDARY SCHOOL BIOLOGY TEXTBOOK – USING CONCEPT MAPS FOR ANALYZING STUDENTS NEW KNOWLEDGE

Imbi Henno & Priit Reiska, University of Tallinn, Estonia

Email: imbi.henno@tlu.ee

Abstract. Textbooks play an important role in science classrooms and it is essential to investigate the reading levels of textbooks, particularly in the area of the sciences. The main objectives of the study were: to explore the number of new concepts in the learning text for students and to analyze the difficulty of text; to explore the acquisition of new knowledge by the students using the „expert" concept maps; and to compare gender differences and students' with different beliefs in their own academic abilities in science. 118 students from urban secondary level schools in Estonia participated in this study. This study revealed that a lot of scientific concepts in twelve-grade biology textbooks (Viikmaa, Tartes, 2008) were unknown and difficult for Estonian upper-secondary students. The students had difficulties with identification of 98 concepts from one lesson. There were many students, who did not know the meaning of more than 15 terms in learning text. Students were classified by beliefs in their own academic abilities into three clusters. A significant difference was found between these three attitudinal groups. Students with above average positive beliefs in their own academic abilities tended to use such concepts as hybridomas, identification of pregnancy, reproductive capacity, strange proteins, monoclonal antibodies, antigens, leukocytes more correctly in completing of "expert" concept map. In the most cases the gender differences tended to be not significant.

1 Introduction

Textbooks play an important role in science classrooms and it is essential to investigate the difficulty levels of textbooks, particularly in the area of the sciences. Merzin (1987) have studied the difficulty of science textbooks. The results suggested that there was a general tendency for school science texts to be over demanding on students' abilities. TIMSS 2003 revealed that on average 80 % of Estonian students taught by science teachers reported using a textbook as primary basis of their lessons and 20% as a supplementary resource (Martin, et al., 2004). If the teachers follow the order and contents of the textbooks and if the textbooks are written very academically, in the lessons the main approach is to deal with concepts of knowledge.

A variety of methods have been used to examine students' understandings and to detect alternative conceptions in biology and science education in such as multiple choice items (e.g. Odom, 1995), using analogy in teaching (e.g. Rule & Furletti, 2004), using the drawing (Özsevgec, 2007), and so on. To promote meaningful learning, Novak (1997) recommend that educators use concept maps as a didactic resource.

2 Theoretical background

Studying the sciences requires an understanding of two things: terminology and concepts. Science textbooks are the ultimate source of science knowledge in many science classrooms. (Chiapetta, Sethna, & Fillman 1991; Shamos, 1995; Henno, 2008). Textbooks often present enormous amount of information (Chiapetta, Sethna,& Fillman 1993; Linn, Clement, Pulos, & Sullivan, 1989) and may give only superficial coverage, which discourages conceptual thinking, critical analysis, and evaluation (Penney, Norris, Phillips, & Clark 2003).

Teachers in Estonia can have an influence on what kind of science textbooks should be ordered. After the restoration of independence in 1991 in Estonia and the implementation of the new curricula after 1996, more than 200 new textbooks and workbooks in science subjects for Estonian basic and secondary schools were developed (Henno, 2008), but it is crucial to realize that Estonian current biology textbooks have some shortcomings.

Teaching upper-secondary school students about cell and molecular biology can be a challenge for a teacher when she/he wants to overcome rote learning of facts without a deeper understanding. The basis for the study of the applied biology is presented in Estonian National Curriculum (Estonian Government, 2002). Within the upper-secondary bio-

logy syllabus, the subject matter of cell and molecular biology is introduced progressively from grade 11th to grade 12th. Different aspects with greater depth of understanding are covered in applied biology lessons in grade 12. Students are expected to master an understanding of basic concepts, content, and terminology in applied biology. Teachers must contextualize the role of textbooks within effective instructional practices.

According to psychologist David Ausubel, language plays a key role in the acquisition of concepts (1968). Joseph Novak argues that "concepts" are what we think with. If we cannot get our concepts clarified and organized; our thinking remains muddled" (1977). What comes to difficult topics – whether difficult for the students as determined by the teacher's previous experience, or difficult for the teacher because of his/her background – using an "expert skeleton" concept map is an alternative. An "expert skeleton" concept map has been previously prepared by an expert in the topic, and permits students to build their knowledge on a solid foundation. "Expert skeleton" concept maps serve as a guide or scaffold or aid to learning in a way analogous to the use of scaffolding in constructing or refurbishing a building (Novak & Cañas, 2006).

Assessment is an integral part of teaching and learning, providing feedback on progress through the assessment period to both learners and teachers. Concept maps can be used for showing the topics/contents, in introducing a topic to the students and for evaluation or assessment (Rice, Ryan & Samson, 1998; Novak, Mintzes, & Wandersee, 2000; Henno, Reiska, 2008).

Learning requires a judgment of the difficulty of a task and the ability to accomplish it. Confidence in abilities in various subjects can influence students' motivation, learning behaviors and general expectations for their future. Positive self-concept can be seen as a desirable outcome variable of education (Branden, 1994). Science achievement and self-concept are key components of scientific literacy. Self-concept measures the general level of belief that students have in their academic abilities. Students' academic self-concept correlates with student success. According to PISA 2006 result, in 48 of the participating countries (including all of the OECD countries) there was a positive association between students' self-concept in science and student performance in science (OECD, 2007: 139).

This paper examined the research question: how can concept mapping as an assessment tool be used for identifying students' knowledge and misunderstandings about the cell and molecular biology.

The main objectives of the study were:

- to explore the number of new concepts in the learning text for students and to analyze the difficulty of text for students;
- to explore the acquisition of new knowledge by the students using the "expert" concept maps;
- to compare gender differences;
- to take into account students' beliefs in their own academic abilities in science to compare, how self-concept connected with student success to finalize "expert" maps.

3 Methodology and data collection

The study of this research took place during the school year 2008/2009, in the twelve grade taught by two biology teachers in urban upper-secondary level schools in Estonia. A total of 118 twelve-grade students, 84 (71.2%) were girls and 34 (28.8%) boys, participated in the study. For this survey the students were asked to bring out all unknown concepts in lesson material "Hybridoma technology and production of monoclonal antibodies" from the 12th grade biology textbook ("Biology for upper-secondary schools II. Applied biology. Human biology" published in 2008). The study consisted of three sessions. At the first step of the study students were given 15 minutes to read carefully a new text "Hybridoma technology and production of monoclonal antibodies". In accordance with the instructions students were asked to circle all scientific concepts they did not remember and underline all concepts, they did not know.

In the next phase the teacher explained the new topic with a Power Point presentation. After the classroom instructions, in the end of lesson, the students` understanding was assessed by using the "expert" concept maps. Students were asked to complete a partially constructed concept map ("expert" map) and an additional attitudinal questionnaire.

Students could not use their textbooks and notes from power point presentation with them when they completed the expert concept-map.

The "expert" concept map as learning and assessment material was drafted by the authors using CmapTools program. This concept map is illustrated in Figure 1. Nine boxes (with bold text inside in Figure 1) were empty for students and students had to fill these blank boxes on their own with concepts from the text. No linking words were left empty. The choice of the nine empty concept boxes was random, but it was meant that the empty boxes would not be sequentially.

The self concept questionnaire included an item battery measuring the students' self-belief as science learners. The measures were taken from a related questions presented in PISA 2006. For attitudinal questions measuring students' beliefs in their own academic abilities in science, students were asked to express their level of agreement using one of the following responses: "strongly agree", "agree", "disagree" or "strongly disagree". The study included 5 items to measure students' science self-concept: How much do you agree with the statements below?

1. I can usually give good answers to test questions on school science topics.
2. I learn school science topics quickly.
3. School science topics are easy for me.
4. I can easily understand new ideas in school science.
5. I can understand the concepts very well.

Sixth question was about difficulty of text: Learning text "Hybridoma technology and monoclonal antibodies" was comprehensible.

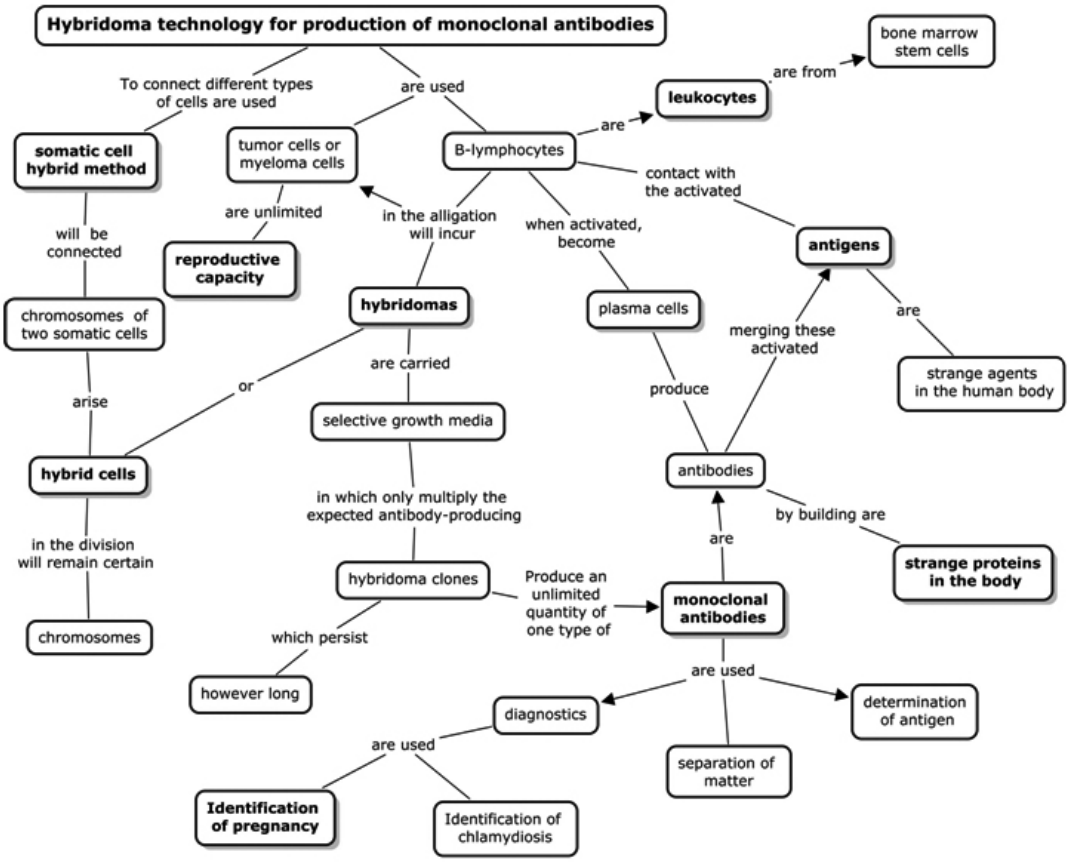

Figure 1. An example of a expert constructed concept map to show how the hybridoma technology is used for production of monoclonal antibodies

For this study, a quantitative approach was adopted. Students' completed "expert" concept maps are assessed mainly counting valid and invalid concepts. The scientific terms from the text mentioned or not mentioned by the students were coded. Descriptive statistics was used to determine frequencies of difficulty, moderate and easy biology concepts as perceived those students. Test of significance were undertaken using t-test, chi-square statistic, ANOVA and cluster analysis.

4 Results

Bordt, et al., have shown (2001) that at the junior high school level many students begin to lose interest in science or develop the view, that science is too hard. Yager`s (1983) review of 25 the most commonly used science texts in K-12 classrooms indicated that more new science words were introduced in those texts than foreign language words in foreign language texts. We found the same tendencies. A total number of words in learning text were 782 (including 186 scientific biology terms). The study revealed that students had difficulties with identification of 98 concepts. There were many students (41), who did not know the meaning of more than 15 terms in the text. Students circled or underlined 96 concepts. The most frequently mentioned unknown and forgotten concepts were: B-lymphocytes; choriogonadotropin; hypophysis; lymphocytes; myeloma; pathogen; plasma cell; somatic cell hybrid method; toxins. Chi-Square($\chi 2$) test was used to examine differences between gender. In most cases the results of independent t-test did not indicate significant difference between genders. Only in some cases: hybridoma technology for production of monoclonal antibodies; chromosome; chlamydiosis; chlamydia test; chromosome the significant difference was found between genders. Males were claimed to know these concepts less.

Students form views about their own competences and learning characteristics. Self-concept measures the general level of belief that students have in their academic abilities and academic self-concept strongly correlates with student success. Their evaluation is based on their position relative to other students and their relative performance on different school subjects (Marsh, Byrne & Shavelson 1988). On average, only 41% of students reported that they strongly agreed or agreed that they could usually give good answers in science tests. Overall, a large proportion of students said that they were not confident in learning science, 56% of students reported that they did not agree that they learned school science topics quickly, 64% of students understood concepts or 62% of students understood new ideas very

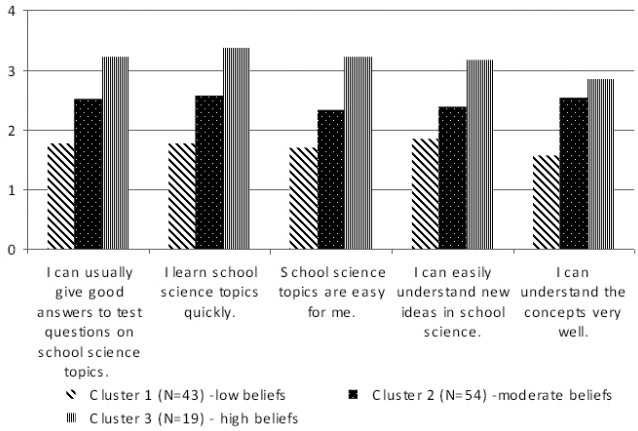

Figure 2. Students demonstrated beliefs in their own academic abilities.

well. Furthermore, 35% agreed that school science topics were easy. On average, only 26% of students agreed that the learning text „Hybridoma technology and monoclonal antibodies" was comprehensible. The t-test was used to study gender differences. The results of independent-t test indicated no differences among groups in self-reported attitudes.

Cluster analysis was used to identify natural groupings within the study cohort. Students were classified by beliefs in their own academic abilities into three clusters. Cluster 1 (Nstud=43) demonstrated low beliefs in their own academic abilities. Cluster 2 (Nstud=52) demonstrated moderate beliefs and Cluster 3 (Nstud=19) above the average positive attitudes, greater confidence than students in the other two Clusters (Figure 2). The students in the third group

agreed in the comparison with other groups much more with the statement that learning text "Hybridoma technology and monoclonal antibodies" was comprehensible.

The ANOVA function of SPSS was used to determine statistically whether these groups exhibit different patterns in using valid concepts in "expert" concept maps. One way ANOVA revealed significant differences between these three attitudinal groups. ANOVA revealed a significant main effect for concept hybridomas ($F=3,97$, $p < 0,022$), identification of pregnancy ($F=4,27$, $p < 0,016$), reproductive capacity ($F=3,33$, $p < 0,039$), strange proteins ($F=7,03$, $p < 0,001$), monoclonal antibodies ($F=6,95$, $p < 0,001$), antigens ($F=3,50$, $p < 0,033$), leukocytes ($F=3,27$, $p < 0,042$). This means that students with above average positive beliefs in their own academic abilities tended to use these concepts more correctly in completing "expert" concept map. ANOVA did not reveal a significant main effect for concepts: hybrid cells, somatic cell hybrid method. The results of Chi-Square ($\chi 2$) test did not indicate the significant differences between frequencies of genders using the correct concept. The only difference was found with the concept: somatic cell hybrid method. Valid concepts were given by 38,1% of females and 23,5% of males.

An analysis of the "expert" concept maps revealed that students demonstrated an understanding about focus question: "Hybridoma technology and production of monoclonal antibodies". The most known concepts were: antigens (78% of students have mentioned) and hybridomas, (74%), and identification of pregnancy (58%). The most unknown concept was monoclonal antibodies (26%). Most commonly students (40%) wrote an invalid term in place of concept monoclonal antibodies. Blank was most often left in place of a concept strange proteins and somatic cell hybrid method (Table 1).

	Correct	Incorrect	Blank box
antigens	79,8%	6,1%	14,0%
hybridomas	73,9%	12,6%	13,4%
identification of pregnancy	57,5%	5,3%	37,2%
leukocytes	57,9%	11,2%	30,8%
reproductive capacity	61,5%	6,3%	32,3%
hybrid cells	50,0%	13,2%	36,8%
strange proteins	38,3%	12,2%	49,6%
somatic cell hybrid method	34,2%	16,2%	49,6%
monoclonal antibodies	26,3%	40,4%	33,3%

Table 1. The percent of students using valid and invalid concepts in finishing partially generated concept map by expert.

Table 2 present the percent of students with different beliefs in their own academic abilities using valid concepts in finishing partially generated concept map by expert

Concepts	Low beliefs in their own academic abilities	Moderate beliefs in their own academic abilities	High beliefs in their own academic abilities
somatic cell hybrid method	25,6%	37,0%	47,4%
hybrid cells	41,9%	55,6%	57,9%
reproductive capacity	55,8%	72,2%	89,5%
hybridomas	62,8%	81,5%	89,5%
leukocytes	51,2%	61,1%	84,2%
antigens	69,8%	83,3%	94,7%
strange proteins	25,6%	40,7%	73,7%
monoclonal antibodies	25,6%	40,7%	63,2%
identification of pregnancy	44,2%	63,0%	78,9%

Table 2. The percent of students in different attitudinal clusters using valid concepts in finishing partially generated concept map by expert.

5 Summary

Textbooks play an important role in science classrooms and it is essential to investigate the reading levels of textbooks, particularly in the area of the sciences. This study revealed that most scientific concepts of the learning text "Hybridoma technology and production of monoclonal antibodies" in twelve-grade biology textbook (Viikmaa, Tartes 2008) were unknown and difficult for Estonian upper-secondary students. It was found that students had difficulties with identification of 98 concepts. The learning text for the student's should be comprehensible. German experts evaluating the learning texts have shown that the texts can be characterized by four essential characteristic: simplicity, structured, brevity, attraction (Groeben, 1982). This textbook lists lesson-by-lesson content objectives, main ideas, important concepts, and comprehension questions that students need to understand, but the analysed section of applied biology textbook is written in a way, as students have as much prior knowledge as authors do. The nowadays Estonian students' lack of interest and low motivation to learn biology may be related to the increasingly sophisticated materials in biology textbooks.

Students were classified by beliefs in their own academic abilities into three clusters. In the comparison with other groups , students in the third group agreed much more with the statement that learning text "Hybridoma technology and monoclonal antibodies" was comprehensible. The results of Chi-Square($\chi 2$) test did not indicate significant differences between genders. This means that the learning text was difficult for both group – for males and females.

Concept mapping was used in the biology classroom to assess students' present knowledge. It was intended to determine whether the use of "expert" concept maps in the classroom as an assessment tool can identify and address specific misconceptions. One way ANOVA revealed significant differences among these three attitudinal groups. Students with high positive beliefs in their own academic abilities tended to use concepts hybridomas, identification of pregnancy, reproductive capacity, strange proteins, monoclonal antibodies antigens, leukocytes more correctly in completing the "expert" concept map than the lower groups.

Studying biology, using strategies to learn terminology and effectively conceptualizing scientific processes will help students understand the subject. To learn new concepts and for better understanding it is very likely helpful to use the visualization of basic structures or graphically describe the phenomenon. The work with concept maps, in the classroom, requires time and mastery of the elaboration process. Based on these evidences we continue our research on concept mapping as an assessment tool in science education.

References

Ausubel, D. P. (1968). Educational Psychology: A Cognitive View. New York: Holt, Rinehart and Winston.

Bordt, M., de Broucker, P., Read, C., Harris, S., & Zhang, Y. (2001). Science and technology skills: Participation and performance in elementary and secondary school.Education Quarterly Review, Statistics Canada, 8(1), 12-21. Retrieved 15 April 2010 from from http://www.statcan.ca/english/freepub/81-003-XIE/0010181-003-XIE.pdf

Branden, N. (1994). Six pillars of self-esteem. New York: Bantam.

Chiappetta, E. L., Fillman, D. A., & Sethna, G. H. (1991). A method to quantify major themes of scientific literacy in science textbooks. Journal of Research in Science Teaching, 28, 713-725.

Chiappetta, E. L., Sethna, G. H., & Fillman, D. A. (1993). Do middle school lifescience textbooks provide a balance of scientific literacy themes? Journal of Research in Science Teaching, 30, 787-797.

Estonian Government. (2002). Põhikooli ja gümnaasiumi riiklik õppekava (National curriculum for basic schools and upper secondary schools). Regulation of the Government of the Republic of Estonia, No. 56. Tallinn, Riigi Teataja.

Gouveia, V., & Valadares, J. (2004). Concept Maps and the Didactic Role of Assessment In A. J. Cañas, J.D. Novak, F. M. Gonzales (Eds.) Concept Maps: Theory, Methodology, Technology: Proceedings of the First International Conference on Concept Mapping 303-310.

Groeben, N. 1982. Leserpsychhologie: Textverständnis – Textverständlichkeit. Aschendorff, Münster.

Henno, I. (2008). A critique of current educational policies for science teaching based on the Estonian example. In

Rannikmäe, M.; Reiska, P.; Holbrook, J.; Ilsley, P. (Eds.), The need for a paradigm shift in Science Education for post Soviet Societies: research and practice (Estonian example) (pp.263-278). Frankfurt am Main: Peter Lang GmbH.

Henno, I., & Reiska, P. (2008). Using CmapTools as assessment tool in school biology. In A.J. Cañas, P. Reiska, M.K. Ahlberg, J.D. Novak (Eds.), Proceedings of the 3rd International Conference on Concept Mapping. Volume 2. Full papers, part two. CMC 2008, Tallinn, Estonia & Helsinki, Finland, September 22-25, 2008, 682-688 http://cmc.ihmc.us/cmc2008papers/cmc2008-p404.pdf

Linn, M. C., Clement, C., Pulos, S., & Sullivan, T. (1989). Scientific reasoning during adolescence: The influence of instruction in science knowledge and reasoning strategies. Journal of Research in Science Teaching, 26, 171-187.

March, H. W., Byrne B. M., & Shavelson, R. J. (1988). A Multifaceted Academic Self-Concept: Its Hierarchical Structure and Its Relation to Academic Achievement. Journal of Educational Psychology, 80 (3), 366-380.

Martin, M.O., Mullis, I.V.S., Gonzalez, E.J. & Chrostowski, S.J. (2004): TIMSS 2003 International Science Report. Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College.

Merzyn, G. (1987). The language of school science. International Journal of Science Education, 9(4), 483 – 489.

Novak, J. D. & Gowin, D. B. (1984). Learning how to learn. New York: Cambridge University Press.

Novak, J. D. (1977). A theory of education. Ithaca, NY: Cornell University Press.

Novak, J. D., & Gowin, D. B. (1984). Learning How to Learn. New York: Cambridge University Press.

Novak, J., D., & Cañas A., J. (2006). The Theory Underlying Concept Maps and How to Construct. Them Technical Report IHMC CmapTools 2006-01 http://cmap.ihmc.us/Publications/ResearchPapers/TheoryCmaps/TheoryUnderlyingConceptMaps.htm

Novak, J., D., Mintzes, J. H., & Wandersee J.D. (2000). Assessing Science Understanding: A Human Constructivist View, 2000 Academic Press: San Diego.

OECD (2007). PISATM 2006 Science Competencies for Tomorrow's World. Volume 1 – Analysis. Paris: OECD

Odom, A., L. (1995). Secondary and College Biology Students' Misconceptions About Diffusion and Osmosis. The American Biology Teacher 57, 409-415.

Özsevgec, L., C. (2007). What Do Turkish Students at Different Ages Know About Their Internal Body Parts Both Visually and Verbally? Journal of Turkish Science Education, 4/ (2) 31 – 44.

Penney, K., Norris, S., Phillips, L., & Clark, G. (2003). The anatomy of high school science textbooks. Canadian Journal of Science and Mathematics and Technology Education, 3, 415 – 436.

Rice, D., Ryan, J., & Samson, S (1998). Using concept maps to assess student learning in the science classroom: Must different methods compete? Journal of Research in Science Teaching, 35(10), 1103 – 1127.

Rule, A. C., & Furletti C. (2004). Using Form and Function Analogy Object Boxes to Teach Human Body Systems. School Science and Mathematics, 104: 155-169.

Shamos, M. (1995). The myth of scientific literacy. New Jersey: Rutgers University Press.

Tekkaya, C., Özkan, Ö., & Sungur, S. (2001). Biology Concepts Perceived as Difficult By Turkish High School Students. Journal of Hacettepe University Education Faculty. 21, 145-150.

Viikmaa, M., & Tartes, U. (2008). Bioloogia gümnaasiumile II osa. Rakendusbioloogia. Inimene. (Biology Textbook: Biology for upper-secondary school II. Applied biology. Human biology) Tartu: Eesti Loodusfoto.

Yager, R. E. (1983). The Importance of Terminology in Teaching K-12 Science. Journal of Research in Science Teaching, 20(6), 577-588.