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Using Concept Mapping Method for Assessing Students' Scientific Literacy

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Abstract

The Natural Science Education Standards (NSES) has defined scientific literacy as knowledge and understanding of scientific concepts which helps us to make personal decisions, participate in cultural and civic speculation and take part in economic productivity. In order to assess students` cognitive components of scientific literacy we need a reliable and valid instrument, appropriate for the survey and easily usable by students, teachers and researchers. The aim of the study is to evaluate concept mapping as an assessment tool for determining cognitive aspects of scientific literacy. Students` concept maps can be assessed by different measures, for example, number of concepts, number and quality of propositions, concept centrality, size and hierarchy of the concept map, clusters in the maps. Our aim is to identify measures which are relevant and valid for assessing students` cognitive components of scientific literacy. Concept mapping was used as an assessment method in an Estonian large scale study (LoteGym, 2011-2014). The results from the PISA-like test were compared with the results obtained from the concept maps. The correlation analyses showed that as a predictor for students' cognitive components of scientific literacy are better suitable the quality measures of concept mapping (e.g. number of high quality propositions). The analysis of the concept maps also showed, that students intend to create more propositions inside the "everyday life" cluster than inside the "subject" cluster or between these two clusters.

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Keywords: concept mapping; scientific literature; assessment tool; cognitive learning.

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1. Introduction

The main goal of the current study is to find an assessment tool to investigate cognitive aspect of students` scientific literacy. However the term "scientific literacy" has become an internationally well-known slogan from educators, researchers, politics and parents and it is still difficult to give an unambiguous meaning (Laugksch, 2000). The importance of the scientific literacy is revealed in school curriculums standards in many countries (including Estonia) and in international studies (e.g. Program for International Students Assessment (PISA) study, OECD).

Concept mapping is not only a learning method, but also used as an assessment tool (Novak, 2007). An assessment related question which can be considered - how to measure students` cognitive components of scientific literacy using concept mapping techniques? To evaluate the responses obtained PISA-like test results are compared with the results of the concept maps. This is the first large scale study, where a concept mapping technique is used together with another testing approach (PISA-like test for assessing scientific literacy).

A large scale study was carried out in a representative sample of 46 Estonian high schools. Initially students were asked to solve PISA like multiple choice items and free response explanation questions. Then they were asked to create concept maps based on a subject-specific focus question. The results from the PISA-like test were compared with the results obtained from the concept maps.

2. Theoretical overview

2.1. Scientific literacy

Holbrook and Rannikmäe (2009) define scientific literacy as "Developing an ability, to creatively utilize appropriate evidence-based scientific knowledge and skills, particularly with relevance for everyday life and a career, in solving personally challenging yet meaningful scientific problems as well as making, responsible socio-scientific decisions". Roberts (2007) in here consideration of scientific literacy consider this to over two types, labeled type I and type II. While type 1 related to cognitive achievement in science, type II related to competence about science and its interrelationship with everyday contexts, in terms of problem solving, decision making, attitudes and values. These types are often mixed as can be seen by statements on what a scientifically literate students is expected to be able to do (NSES, 1996):

- ask or determine answers to questions derived from curiosity about everyday experiences;
- describe, explain, and predict natural phenomena;
- read with comprehension articles about science in the popular press and to engage in social conversation about the validity of the conclusions;
- identify scientific issues underlying national and local decisions and express positions that are scientifically informed;
- evaluate the quality of scientific information on the basis of its source and the methods used to generate it;
- evaluate arguments based on evidence and to apply conclusions from such arguments appropriately.

On the other hand, the PISA 2015 framework simply suggests a scientifically literate person is able to participate in reasoned discourse about science and technology (OECD, 2013), in type I aspects (Roberts, 2007):

- explaining phenomena scientifically - students recognize and offer explanations for a range of natural and technological phenomena.
- evaluating scientific enquiries - students describe scientific investigations and propose ways of addressing questions scientifically.
- interpreting data and evidence scientifically - students analyze and evaluate data and draw appropriate scientific conclusions.

2.2. Cognitive skills and scientific literacy

Whichever emphasis is placed on scientific literacy, to assess also requires knowledge on how people learn. According to Webb (1997) "Depth of Knowledge" in learning is based on 4 major categories: level 1- recall; level 2 -using skills and conceptual knowledge, level 3 -strategic thinking and level 4 -extended thinking. (OECD, 2013).

According to Hodges (2006) cognitive learning processes are required to:

- Create a prior knowledge – teachers determine student gains about a topic for generate meaningful and long-lasting knowledge.
- Vary learning conditions – teacher use different approaches demanding students to gain skills in using information in unfamiliar ways.
- Re-represent information – by undertaking activities which require re-representation of information but in different ways (e.g. from symbols to words, from numbers to graphs) students increase their ability to handle information.
- Remembering helps – asking students to recall, as in a testing situation requiring connections, helps long term memory retention.

2.3. Concept mapping

Concept mapping was developed in 1972 by Joseph Novak's research team, based on the learning psychology of David Ausubel. The principal idea of Ausubel's cognitive psychology is that learning takes place by assimilation.

In constructing concept maps information already gained is linked with a new understanding. Concept maps are ideal tools to measure the growth of students` knowledge interconnections, because map constructing needs to represent ideas using one's own words. Any misconceptions or incorrect links which appear, indicate a lack of understand. (Akinsanya, 2004) Thus valid concepts and propositions which are put forward by students can significantly raise the level of retention of meaningful learning (Novak, 2006)

While concepts being acquired are new, they can be linked to concepts previously stored in the long-term memory. The outcome is a hierarchically and strongly integrated set of ideas. However, building such knowledge structure is depending on four cognitive processes:

- subsumption - where new, more specific concepts are linked to more general concepts already possessed by the learner;
- differentiation - in which the existing knowledge structure is progressively elaborated, explained and illustrated;
- integration – in which the meaning of a new concept is modified and adjusted in line with existing concepts;
- superordination - in which new, more general, and more inclusive concepts are assimilated into existing concepts in the knowledge framework (Mintzes, 2006).

3. Methodology

Concept mapping and PISA-like test were used as assessment methods in an Estonian large scale study (LoteGym, carried out in 2011-2014). This involved 1614 students in first solving a PISA-like, three dimensional, scenario-based exercise in the field of natural science (based on chemistry, biology, physics or geography). The test consisted of different comprehension level, multiple choice items and open ended questions. Students were then required to compose concept maps.

In this study, 379 students created a subject-specific focus question-based, concept map related to given 30 concepts. These 30 concepts were classified by experts into two categories: "subject" category (concepts from biology, chemistry and physics) and "everyday life." The focus question for this study was: "Milk – is it always healthy?" The concept mapping was carried out using the computer program CmapTools.

Data analyses was carried out in different phases: 1) assessing PISA-like tests (maximum total result of the whole test was 19); 2) assessing the quality of concept by experts' given marks: 0-wrong proposition; 1- daily used proposition; 2- very good proposition with scientific content); 3) assessing the quantity measures of concept maps with using the program Cmapanalysis (Cañas et.al., 2013): taxonomy score, proposition count, orphan count, etc.; 4) correlations between PISA-like test results and concept map measures were calculated in MSExcel.

4. Results of the research

Analyses of the study pointed out that the highest correlation between the PISA-like test and the measures of concept map (r=0,33) appeared between the sum of PISA-like test results and the quality measure "2-scored propositions" from the concept map, assessed with the highest mark by experts.

One of the highest correlations between quantitative measures of concept maps and PISA-like test (r=0,24) appear between the sum of PISA-like test results and the sum of propositions. Correlations between concept maps quantity and quality measures are demonstrated in Figure 1. The quality measure has a higher correlation index than the quantitative. The same phenomenon appears, when 343 chemistry based concept maps are analyzed from the same study (Soika, et. al., 2014).

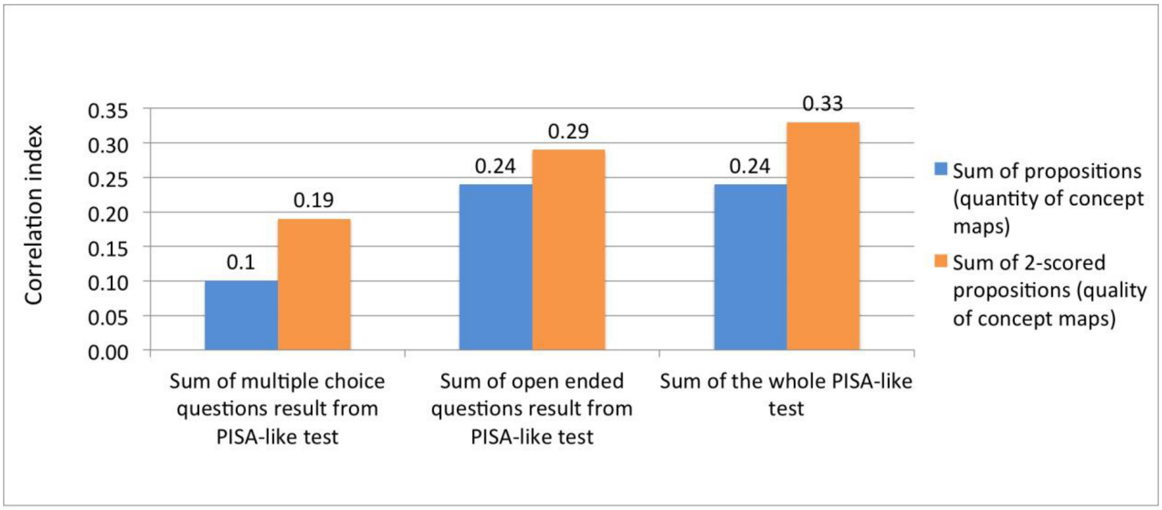

Figure 1 Correlations between parts and sum of the PISA-like test results and concept mapping quantitative and qualitative parameters.

As the sum of 2-scored propositions represents the highest correlation between the whole results for the PISA-like test of interest, the question arises as to what is the connection between the result of the PISA-like test and sum of 2-scored propositions of the concept map. Here, 19 groups of students are formed by taking the sum of the 2-scored propositions of the concept maps. The highest number of created 2-scored propositions per concept maps is 19, but no concept map exists with 18 2-scored propositions. The average results of PISA-like test per groups are illustrated in Figure 2.

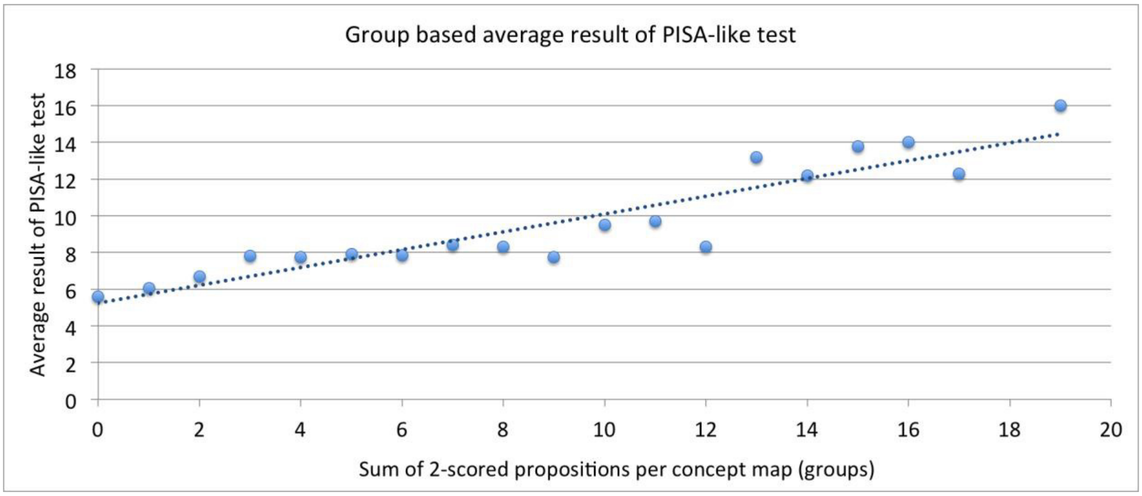

Figure 2 Average results of the PISA-like test for the groups that are allocated by the sum of 2-scored propositions in the concept map.

Figure 2 points out that the result of the PISA-like test depends on the sum of the 2-scored propositions of the concept map, the trend line is rising and the results from the PISA-like test depends on the sum of 2-scored propositions of the concept maps.

In analysing this cognitive approach to assessing students' scientific literacy by a concept mapping technique, it is assumed that attention is paid to the compatibility of propositions and concepts from different clusters. The 30 concepts are separated into two clusters: a) concepts from everyday life (9 concepts) and b) subject specified concepts (21 concepts). Concepts' connectivity inside and between the clusters are compared. The result is that students create more connections between everyday used concepts (7,8% from propositions which are possible to create), than between subject specified concepts (2,9 % from possible propositions), or between everyday used and subject specified concepts (1,9% from possible propositions). The same phenomenon appears in a previous study (Soika et. al., 2014) where clusters are analysed more specific, but the general conclusion give the same outcome.

5. Discussion

Different perspectives are studied, which occur between concept maps and the PISA like test for the purpose of evaluating students` scientific literacy. Although assessing students with the concept mapping technique is debatable, it is still possible to examine the cognitive approach to scientific literacy. The construction of the maps depends on many surrounding factors, which means that interpreting concept mapping data correctly, needs to take into account all conditions of construction. The conclusion reached is that the concept mapping technique can be used for assessment, if the maps are made in equal conditions – students who create more high rated propositions in their concept maps also achieve higher scores in the PISA-like test. Also noticed is that concept mapping give information that is unattainable with other types of tests (e.g. multiple-choice, quiz etc.).

It was assume that researchers and teachers would decide about the cognitive ability of scientific literacy not only by counting the propositions, but also by paying attention to the information that is given about the quality of the propositions and the general structure of the concept map.

The study also showed that it is hard for students to create connections between concepts from different clusters. One reason could be that school teaching is subject based and students cannot easily apply the subject concept to everyday life situations.

Even if it is difficult to fulfil the validity criteria under the different conditions of concept mapping, it is still a useful assessment tool. Educators who decide to use concepts mapping for assessment should make sure that the presumptions to their approach are reasonable.

6. Conclusion

By analysing the results using the assessment methods indicates, students` scientific literacy is shown in a different manner. This suggests that if using concept mapping as a relevant and appropriate instrument for assessing students` scientific literacy, it is very important to play attention to how data is interpreted. It is also important to note that conceptualisations given to students beforehand (concepts, focus question, time range etc.) play an important role in enabling students to create good concept maps. Both content and qualitative characteristics are relevant to evaluate the students` concept maps. In some cases, visually very well constructed concept map do not show scientific literacy in an appropriate way.

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