Improving E-Textbooks: Effects of Concept Maps

Santeri Saarinen, Pentti Hietala, Mirjamaija Mikkilä-Erdmann,
Pekka Mäkiaho, Timo Poranen, Markku Turunen

Abstract: This paper studies the effects of teacher-created concept maps in improving e-textbooks. The implemented application was tested with 99 university students. Preliminary analysis of the logdata from the test sessions shows that the use of concept maps in e-textbooks encourages users to interact with the application instead of just reading the information offered.
Key words: Concept maps, e-textbooks, mobile learning.

INTRODUCTION

In our digital age electronic textbooks are entering the classrooms and are deemed by many to replace paper textbooks. It is easy to list their potential benefits, e.g. Murray and Perez [6] mention "widespread accessibility, interactivity, increased visual appeal and dynamic linking to supplemental materials". However, previous research suggests that learning outcomes seem often not to differ from those using the printed textbook [10, 6].

Thus plain text in electronic form does not bring significant benefits. One solution is to provide additional representations of the e-text, for example with cognitive maps, as we have done in our study. We aimed to find out how different navigational tools affect students' learning outcomes, and how their studying patterns differ when using different navigational tools. We selected concept map as the main tool to use with e-textbooks, because it appears to be an effective tool for learning in natural science (see e.g. [4]) and also because of its novelty value in the field of e-learning. As mentioned in our previous paper, to our knowledge, no previous research exists on the use and efficacy of concept maps in e-texts in Finnish higher education. This project aims to fill these gaps in the research of education, science instruction and learning technologies. [5]

BACKGROUND AND RELATED WORK

Concept Maps are graphical tools for organizing and representing knowledge. Their main elements are concepts (usually enclosed in circles or boxes of some type) and relationships which link two of these concepts to create a meaningful statement or proposition in the form of a diagram [7]. Both concepts and links are named.

One of the main applications of the concept maps has been to support reading and writing activities and we can find three ways of doing it: building a concept map from scratch, fixing a previously built concept map and studying a ready-made concept map [11]. There is an evidence that each of these activities can increase the students' understanding of the studied material (see e.g. [2, 3]). Moreover, concept maps can be added to existing educational software to boost the students' learning achievement and decrease their cognitive load (see e.g. [4]) for a study where a concept map was embedded in an educational computer game).

In this paper we are interested in the third alternative, namely studying a ready-made concept map that has been created by the teacher of the key topics of the text. In fact, there are results that presenting this kind of a worked-out map enhanced learning most effectively of the alternatives [3].

One important aspect of ready-made concept maps is their assistance on student navigation inside the learning material. Earlier research before mobile devices and e-textbooks focused on hypertext navigation. Promising results were obtained for example from the ComPASS system [8] which provided the students with a relational dynamic concept map of the studied text. The map was an interactive one with a fish-eye view of

the focal concept presented always in the middle of the map view as enlarged. This kind of dynamic concept map allowed students to pursue their own learning goals more easily which produced good learning results [8].

In this paper a biology e-textbook is accompanied with a ready-made concept map view and a ready-made index view. The concept map provided a hierarchical view of the material. As for the topic area of our e-textbooks, we concentrate on natural science texts, because it has turned out that in this area student teachers have several misconceptions, e.g. concerning photosynthesis [1]. Indeed, an important aspect of our research is the quality of the e-text. As mentioned in [5], we have designed the e-texts so that the paragraphs point out typical misconceptions concerning photosynthesis, and discussed concept pairs such as energy versus matter, nutrients versus nourishment, and plants versus animals. These concepts are chosen based on the previous literature, which has shown that they are often misunderstood by children and adults.

EAGER APPLICATION

To test the effectivity of concept maps to help students to study by using e-textbooks, we developed a web-application called Eager. This was optimized to be used with Safari web browser on iPad Air tablet with 9.7" screen and 2048 x 1536 resolution on iOS version 7.0.4. The application consists of two separate but linked parts. The figures below (Figures 1 and 2) show both of the versions of Eager dealing with the domain of photosynthesis. Both versions have some common elements on the left side of the screen, which contains the traditional e-text. The button shown at the top of the screen, next to the title of the text, is used to resize the screen, toggling which side of the screen takes up to two thirds of the screen space available. The text next to the button is similar in both versions. Its only interactive parts are the terms marked with blue text. These are the main concepts that the students should learn from the text. These are defined by the teacher and saved in XML-format with the rest of the text in separate tags, which identify the term, and the id of an element where the application should navigate when the term is clicked.

Figure 1 shows the version which has index as a navigational tool. In this version, the important terms and their definitions and other concepts defined by the teacher are presented in an index, which contains separate blocks, under which all terms belong (in this case, blue block; titled "Ravinto" (Nutrition), orange block; titled "Ravintoketjut" (Food chains), and green block; titled "Fotosynteesi" (Photosynthesis)). Within these blocks, the different terms are organized in a hierarchical system. Whenever a term is clicked in the text, that term is highlighted in the index. Also the whole block to which it belongs is bolded, so that the user better understands the complete hierarchy to which this term belongs to.

Figure 8 - Index version of Eager application

Figure 2 shows the other version, which has concept map as a navigational tool. Here the terms and their connections are defined in a network, which contains different kind of nodes, based on what kind of information is presented in the nodes, and connections between the nodes. The nodes are also color-coded similarly to the index version. Moreover, the nodes are clustered and placed in certain positions to better describe their connection to other nodes. All this is defined by the teacher, who can freely edit the concept map, and then an XML definition is created, from which the actual graphics are built using d3.js library. For example:
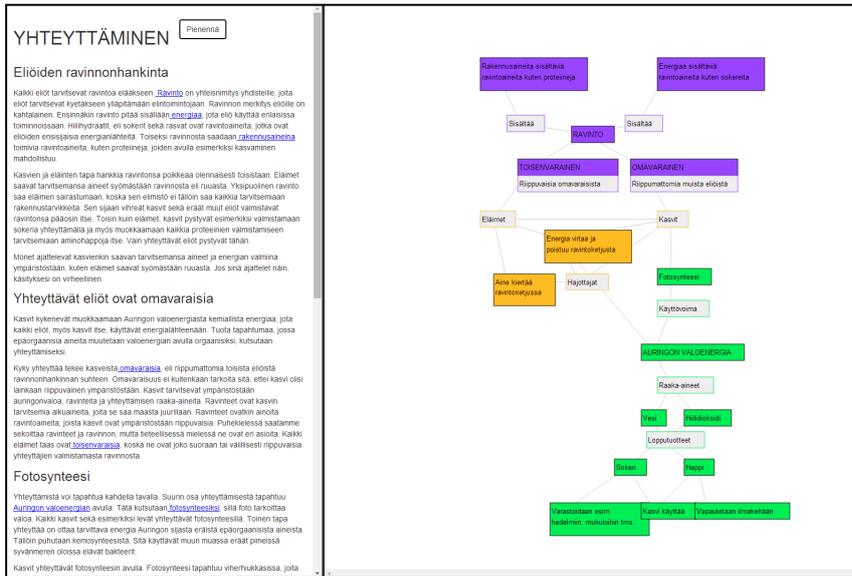
Figure 9 - Concept map version of Eager application

<node nodeID="0003" nodeType="4" x="580" y="370" extraText="Riippumattomia muista eliöistä" nodeGroupId="1">OMAVARAINEN</node>

In this example we have one node, containing the text "OMAVARAINEN". The nodes position is defined by *x* and *y* attributes. The *nodeID* attribute defines the id of the node. This is used in connection to the text XML, where the *targetNode* attribute defined the node to which that word was connected to. The *nodeType* attribute defines what kind of node the one in question is. In this example, type 4 means a node which has a box of extra text connected to it. The contents of this box are defined in the *extraText* attribute. Lastly, the *nodeGroupId* attribute defines to which group the node belongs to, so the whole group can be accessed at once when needed.

Whenever the user clicks a word in the text in this version, the corresponding node is highlighted. It changes color slightly, the text is bolded, and the screen is scrolled, so the selected node is shown in the middle. Additionally, the whole group to which it belongs to is highlighted with a slight recoloring. The nodes in the concept map also work as links to the opposite direction, meaning that when you click a node, it selects that word in the text, and scrolls the text to the spot where that word appears for the first time.

Eager application was developed as basic web-application which can be accessed with any browser on any device. The base of both versions is an html page, which contains the containers for both sides of the UI. These are the dynamically filled by parsing the data provided in XML-format with javascript, and then using this data two populate the interface. The concept map graphics created using d3js library, which provides graphical representations to data which can then be updated dynamically as needed. The web application is running on a virtual server which can be accessed through HTTPS calls that connect to a php scripts which are used mainly for saving the log data to text files, which are stored on the server.

AN EVALUATION STUDY

The application was tested in the premises of University of Turku in spring 2014. Ninety nine native Finnish-speaking second-year students from the faculty of education

took part in the tests. They were divided in four predetermined groups by their teacher, who was also supervising the evaluation session. The first two groups tested the application on 8th of May, 2014 and the other two groups on the following day. On top of these four evaluation sessions, several students who were not able to attend these days, took part in separate sessions between the 15th and the 16th of May.

The evaluation consisted of a ninety minute session during which the students did three separate parts. The total time was limited but the students were free to use as much time as they wanted for each of the test's parts. Everyone finished clearly ahead of the planned schedule, so we can safely assume that students were able to spend sufficient time with the application during the test. Firstly the participants filled in a pre-test survey, in which they answered some background questions, and answered questions about the subject studied with the application, which in this case was biology. After answering the questions, the participants were instructed to study the subject using the application developed. No other studying material was allowed during these evaluations. After they felt they had studied enough, the participants answered the same questions about the subject again that they had answered before the studying period. During this time, they were allowed to change their earlier answers, if they felt they had gained new information while studying. Finally, the participants answered a user experience questionnaire, with which we obtained information about their feelings towards the application we had developed.

All the answers from the users were collected on a paper and then saved in digital format for analysis later on. On the top of the subjective answers from the participants, we gathered log data from the usage of the application. This was done through a php script which saved each button click, the users did, to text files. These logs allow us to follow the use patterns of the participants and to learn how the students are using electronic learning material while studying.

RESULTS

In this section we will present some preliminary results based on the logged data from the evaluations. We will not give the results from the actual learning outcomes, as that analysis is still going on, but concentrate more on the technical side, and how the application was used during the evaluation. This is important, because the use patterns can show us how the use of different navigational tools affects the use of the application.

The students used the application on average 12 minutes and 48 seconds, while the median time was 10 minutes and 1 second. There was a small difference between the two versions. The users who had concept map as a navigational tool, used the application on average about a minute longer than the ones who had index as a navigational tool. The users used the application for a shorter period that was anticipated by us. This was probably because of the familiarity of the subject and the short length of the studied material. In future versions, we are planning to use more difficult and longer tests, to get more accurate results of people actually learning new things through larger amount of material, which is more similar to actual e-material used in university courses.

We also collected data on how the application was used. Each button click was tracked and saved. In this application there were four possible actions the users could perform on top of reading the study material: minimizing the text, minimizing the navigational tools, clicking a term in the text to gain more information and clicking a node in the concept map to see where it appears in the texts. In general these actions were done very rarely. On average the users did 3.08 actions during the use of the application. There were small differences between different versions. Students with the concept map version did on average 3.54 actions, while index users performed only 2.61 actions.

However, there were a lot of users who accomplished no actions at all. 45 out of 99 users did not click anything during the whole test sessi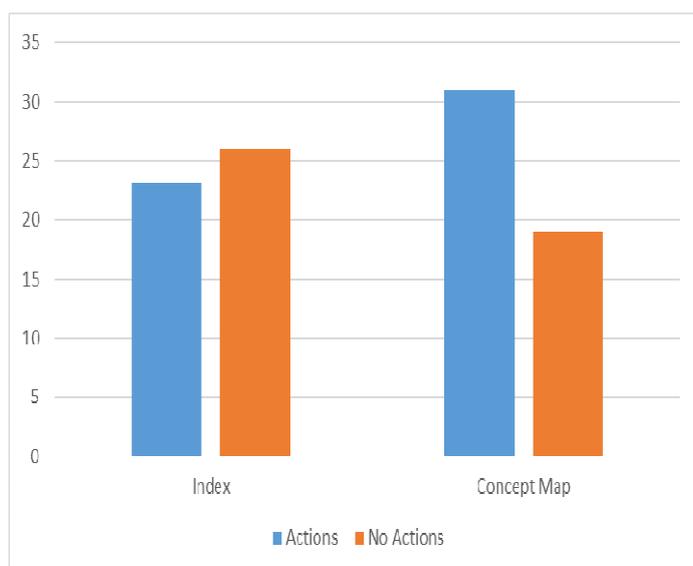on. If we ignore these users in the averages, and only account for the users who actually did something with the application, the differences between versions become negligible (5.56 for index vs 5.71 for concept map). What is interesting though, is that the number of the users doing something was significantly larger in the concept map group. Actions were recorded for 62% of concept map users, while for index users, this number was only 47%. From this we can conclude that having visual navigational aids, such as the concept map, could encourage users to try different actions when using the application.

Figure 10 - Active vs Non-active users

CONCLUSIONS AND FUTURE WORK

In our study with the students of University of Turku, we found out that for active readers (by which we mean users who used the navigational tools on offer in the e-material while studying during the test sessions), it did not matter which version of the application they used, the concept map or the index one. In both versions, the amount of activity, in other words, the number of clicks while studying, was very similar. However, we could find a clear indication that having a visual navigational aid, such as the concept map, encouraged the users to be more active with the application. The bar to move from being inactive reader of an e-text to an active user of e-textbook application was lowered significantly.

It would be interesting to see how the activity of the users while studying affected their learning outcomes. This will be one of our research questions when analysing the data further, and hopefully we can find a clear link which shows that the use of concept map as a navigational tool positively affected the learning outcomes. One possible reason for this could be that the students who used the concept map version of the application had to interact with the application more and thus gained more information. This would expand on the results of Reader and Hammond's [9] study, where they found concept map to be more effective learning tool than a notepad and noted that "One possible explanation for the substantial difference between conditions is that for some reason subjects in the concept mapping condition spent more time reading the material in the hypertext system than did those in the note tool condition and thus retained information more effectively".

Additionally, we are planning to expand our study further. In the next version of the application we plan to use even more visual aids, for example pictures and graphs, to scaffold the students learning still more with different kind of stimuli. Another possibility would be to offer the students the choice of building their own concept map based on the information gained from the e-text. This kind of activity would be in line with the results of Reader and Hammond [9] and might further improve the learning outcomes.

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ABOUT THE AUTHORS

PhD student Santeri Saarinen, MSc, School of Information Sciences, University of Tampere, Finland, E-mail: santeri.saarinen@uta.fi

University lecturer Pentti Hietala, Phil. Lic., School of Information Sciences, University of Tampere, Finland, E-mail: pentti.hietala@uta.fi.

Professor Mirjamaija Mikkilä-Erdmann, PhD, Department of Teacher Education, University of Turku, Finland, E-mail: mirmik@utu.fi.

PhD student Pekka Mäkiaho, MSc, School of Information Sciences, University of Tampere, Finland, E-mail: pekka.makiaho@uta.fi.

University lecturer Timo Poranen, PhD, School of Information Sciences, University of Tampere, Finland, E-mail: timo.t.poranen@uta.fi.

Professor Markku Turunen, PhD, University of Tampere, School of Information Sciences, Finland, e-mail: markku.turunen@uta.fi.

The paper has been reviewed.