

The Living Textbook: Towards a new way of Teaching Geo-Science

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Abstract

Textbooks of the future are completely different from the analogue printed textbooks we are used to. They are digital, provide different ways to view the same content, allow for multiple (individual) learning tracks and can be regularly updated. They are not stand-alone sources of information but link to all kinds of other information sources. In this paper we present the Living Textbook that consists of a collaborative website (textbook) accompanied with an interactive diagram (concept map) showing the course's concepts and their relationships. The Living textbook was implemented for a number of introductory courses in GIS and Earth Observation and was tested with a group of E-learning and face to face students. Results show that the development of an ontology forces teachers to rethink their course content, make links with topics of other teachers explicit and remove redundancy. For students, the main advantage of using a Living Textbook is the overview it provides of the course content and the expert knowledge network of their teachers.

Keywords: Ontology, Web-based Textbook, Concept Map, Education

1 Introduction

Web and Ontology-based textbooks are mainly used in web-based education, yet they are also very useful in face to face education. An ontology is a set of concepts and relationships within a certain application domain. For educational textbooks they can be regarded as a conceptualisation of the learning content, the topics to be studied and the relationships between these topics. Web-based textbooks can be important tools to provide course content in a more personalized non-linear way, whereby students decide in which order they study the concepts and if they require additional information (other concepts) to master a topic. Web-based textbooks are now becoming collaboration tools in which faculty and/or students develop digital textbooks together (Ravid et al., 2008, Neumann and Hood, 2009). According to Gu et al. (Gu et al., 2015) we have reached the step where we are re-thinking what a textbook should be like, rather than re-creating the printed books we used to have. This includes the way textbooks are created (moving to a more systematic conceptual design), the practical instructional strategies (like enriching the textbook with a visual representation), content update strategies, and the development of different learning paths.

2 Living Textbook

We have created an interactive Web-based textbook which we call the Living Textbook. The term "Living" refers to the fact that our textbook has no fixed content order, uses dynamic visualizations and provides information at different abstraction levels. The Living Textbook is founded in the concepts of Instructional Design (ID) (Reiser and Dempsey,

2007). ID starts with the identification of reusable blocks of learning content, the core concepts within a certain course. Core concepts and the relationships between these concepts are often referred to as the ontology (Uschold and Gruninger, 1996), the molecular structure of the course and the subject area. Our Living Textbook is based on a teacher-defined ontology. Earlier similar approaches such as [7] have not yet shown an in-depth integration with the course materials and involvement of lecturing staff as much as we aim at in our project.

2.1 Teacher defined Ontology

The design of the Living Textbook has been based on the content of the current textbook (ITC, 2012) and knowledge of the teachers. The reason for this is that we would like to encourage the involvement and commitment of the teachers, but more importantly the fact that we want the content and concepts to be living, in the sense that they can change. The advantage of this is that old topics can be dropped and replaced by new ones. An important element in a domain as dynamic as GI-Science.

We identified a group of experienced teachers in GIS and Earth Observation and asked them to develop a simple ontology for their course: the key concepts and basic relationships between them, such as subclass relationships, "is used by", "is represented by", etc. This was done in a stepwise way: first each teacher created an individual ontology for their own topics, followed by a workshop in which these were discussed. Then each teacher identified links between his/her topic and other topics in the same course, followed by an

interactive workshop resolving problems and creating a consistent integrated ontology.

The ontology was created in the yEd graph editor using a pre-defined set of 13 relationships. After finalization, the ontology was converted to a web-accessible concept map. The current ontology contains approximately 250 concepts. We did not restrict the number of concepts per graph and on purpose included several subtopics in the same graph to show the links between these topics.

2.2 Concept Map

A concept map is not the same as an ontology though they share a common feature of being used for representing and communicating knowledge. Ontologies are representations of concepts and relations, captured and formalised using formal descriptive languages such as the Web Ontology Language (OWL). Concept maps, in turn, are the result of visually representing concepts usually enclosed in circles or boxes of some type, and relationships between concepts, indicated by connecting lines between concepts [8]. In a concept map, concepts and relations are labelled in such a way that two connected concepts and a relation between them form a meaningful statement. Ontologies can be used as underlying source of information to produce concept maps.

We created a concept browser, an interactive tool that helps students in navigating through course content on a high conceptual level. It uses the concept map (based on the domain ontology of GIS and Earth Observation, as mentioned in Section 2.1.), which is designed to optimally convey the conceptual structure of the course content to the student.

The concept map is also fully integrated with the web-based textbook content. Selecting a concept in the concept map will update the visual content of the textbook and vice versa. As concept map and textbook are shown in the same screen, the student can visualize information at different hierarchical levels (main concept relationships and a more detailed description of these concepts) at the same time.

2.3 Use of the Living Textbook

Within an educational setting the living textbook can be used in different ways. In the courses described in this research, the Living Textbook was used in the following ways:

- As a tool for concept exploration to identify knowledge gaps at the start of the course. For this type of use students mainly use the concept map and compare it with their pre-knowledge to determine their learning path.
- The use of the tool during exercises for which information in the Living Textbook was needed. In this case the students can choose to start in either the textbook side or the concept map of the Living Textbook.
- During Virtual Classroom presentations in which students gave an overview of course topics. In their slides they showed pictures of parts of the concept map to show the relationships between concepts (only use the concept map).
- The use of the tool in the exam preparation phase in which the student used the tool to review the course content and check the understanding of the topics

(This can be done either via the concept map or by only using the textbook part).

3 Setup of the Experiments

The use of the Living Textbook was evaluated in three introductory GIS courses. The evaluation of the tool was split in two phases. The first evaluation was based on a prototype version of the tool and took place in March and April 2017.

In this phase the tool was tested with two groups of students. Semi-structured interviews were conducted with a number of distance learning MSc students (4) and speak aloud experiments were conducted with a group of face to face students (6). In addition, semi-structured interviews with teachers were conducted (6). More details about these tests can be found in Walsh (Walsh, 2017).

For the semi-structured interviews different aspects of the tool were evaluated:

1. Student engagement in using the tool
2. Usability of the tool
3. Teacher perspective on the pedagogical value of the tool

Student engagement was tested for three different aspects: *behavioral engagement*, *emotional engagement* and *cognitive engagement* (Fredricks et al., 2004). Behavioral engagement is defined as the sustained use of digital learning aids or participation in technology mediated environments, in this case the Living Textbook. Emotional engagement is evaluated in negative (frustration and anxiety) and positive (enthusiasm and enjoyment) sense. Cognitive engagement is the focused effort learners give to effectively understand the content and emotional engagement refers to the feelings students have about their learning experience (Fredricks et al., 2004).

The usability of the tool is evaluated using the following categories: *content*, *interactivity*, *navigation*, *appearance* and *accessibility*. For the teachers the use of the tool was evaluated based on the potential benefits that teachers see for students, potential benefits that teachers see for themselves, potential concerns teachers have for students, and potential concerns that teachers see for themselves.

After the first evaluation the tool was further improved and a second evaluation took place in October 2017. In this phase the evaluation was conducted via a digital survey given to face to face students. The students were asked to score on a scale from 1 (not useful at all) – 4 (very useful):

- How useful the concept map of the Living textbook was
- How many times they used the Living textbook
- How they used the Living textbook

For the use of the Living Textbook the following categories were specified: reading, searching, overview of concepts, insight in relationships, find specific textbook pages.

The difference between the first and the second phase test groups is that the first group of students only received the Living Textbook and the second group of students received the Living Textbook in addition to hard-copy traditional textbook with the same content.

3.2 Student Evaluation (phase 1)

The results in this section are based on the findings of Walsh (Walsh, 2017) who conducted the student evaluation. His results show that different groups of students used the Living Textbook in different stages of their studies, ranging from students that indicated that they used the Living Textbook a lot throughout their course and for different learning activities, to students that first acquired knowledge in other ways (e.g. via exercises) and students that used the Living Textbook only occasionally.

For the emotional engagement what caused frustration were the interoperability between concept map and textbook and the fact that the number of concepts was overwhelming and students felt lost as they did not know where to start. On the positive side, the fast and free navigation was appreciated and students are enthusiastic about the freedom to explore the topics.

For the cognitive engagements students indicate that the Living Textbook helped them to understand how concepts are linked together and where a concept fits in relation to other concepts. The Living Textbook helps students to keep the bigger picture in mind.

For the Usability the students appreciated the overview the tool provides (*Content*) in different phases of the learning process. In the beginning of their course to get an overview of the content but also at the end of the course (in the preparation for the assessment). Not all relationships between concepts were regarded to be equally informative (e.g. Used by – not very informative).

Several suggestions were made in the category “*Interactivity*” for improving the performance of the tool including improvements for zooming and focusing of the concept map which were already integrated before the second test (phase 2) was conducted.

For “*Navigation*” the concept map was regarded to be very convenient to find data, but a possible improvement point was the readability of the relationships between concepts.

In the category *Appearance* the lack of hierarchy was identified as a point of improvement. More detail about the results can be found in Walsh (Walsh, 2017).

3.3 Teacher Evaluation

The teachers that were interviewed by Walsh (Walsh, 2017) identified the following potential benefits for students:

- Living textbook can increase student competence by allowing them to see relationships between concepts
- Has a potential use as an advanced organizer
- Concept map can create a feeling of interactivity that students otherwise would not have

A current concern for the students is that the number of concepts is overwhelming.

Teachers identify many potential benefits for themselves including:

- Map provides a flexible content management system which will help to implement updates
- Can be used to Identify gaps and inconsistencies in course structure

- Providing a comment layer for teachers could be a valuable planning tool to ensure consistency between courses

Two concerns for teachers are identified:

- The time commitment involved in updating the concept map, particularly if starting to organize concepts by hierarchy or importance
- Large differences in the granularity of modelling between different subjects and topics so it is difficult to build consistency

3.4 Student evaluation phase 2

In the second evaluation phase, students were asked to fill out a digital questionnaire. The usefulness of the concept map of the Living Textbook received a score of 3.2 on a scale of 1-4 (low-high). A total of 45.2% of the students (62) scored the tool with a value 3, 35.5% with a value 4. This is in line with the score of other learning activities for example following a face to face lecture received an average score of 3.5.

Only a small group of students, 16.9% indicates that they used the Living Textbook frequently, most students indicated an intermediate use (61.1%) and 22.1% of the students out of a group of 77 did not use the Living Textbook at all.

The task most often conducted in the Living Textbook was searching for a specific concept. Out of the 60 responding students 55% indicate that they used the Living Textbook for searching. Out of the test group 30% used the Living Textbook to get an overview of topics.

4 Conclusions and Further Work

The process of constructing an ontology has proven to be very useful, especially for teachers working together in the same course. Creating a course ontology forces teachers to identify important concepts and relationships and the visual representation of the concepts makes the identification of redundancy easy. This approach can however also be a potential weakness as quality of content depends on the teachers involved. Yet, in our opinion when the number of users is large enough and feedback on the content is collected continuously, this risk can be avoided. We also see possibilities for more interactivity in collaborative editing. The current workflow for creating the underlying ontology is rather sequential. If teachers are provided with a web-based editor to update the content, we expect an efficiency gain in the creation process.

As two different test groups of students were used and the students in the second group were offered an improved version of the Living Textbook in addition to a hard copy book, it is not possible to compare the groups directly. The number of students and teachers for the interviews of phase 1 was low, also compared to the much larger group of students involved in phase 2. Over the coming time period we would like to continue the collection of feedback from students and integrate these experiences in the further development of the Living Textbook. We are setting up a student user group and are planning more experiments with an additional 200 students starting in fall 2018.

Figure 1: Components of the Living Textbook.



During the tests it became clear that the number of concepts in the Living Textbook can be overwhelming. Tools need to be developed to identify groups of concepts to help students to identify a subset of concepts. These tools might be filters based on learning objectives or other criteria. More structure (hierarchy) is needed in the concept graph to make it possible to incorporate more concepts. Implementation of individual learning paths can also steer students through the concepts. These paths can be identified by either students or teachers. An individual learning path is a subset of concepts belonging to the same course that a student needs to study to meet the learning objectives. Where a teacher-defined learning path may contain all required concepts, a student-defined learning path may filter out concepts the student already masters, may start from a different starting point (based on knowledge the student already has).

Work has been done on the GIS&T Body of Knowledge within an educational setting by a number of authors including Ahearn et al. (Ahearn et al., 2013) and Prager and Brandon (Prager and Plewe, 2009). In the creation of the Living Textbook we did not take the GIS&T BoK as our starting point, but the starting point of our research were the current courses at the ITC faculty of the University of Twente. Our content area exceeds the concepts in the GIS&T BoK in some parts but overlaps in the GIS domain. Follow up developments may embark upon loading an existing ontology and displaying this ontology as a Living Textbook for teaching purposes or to link the Living Textbook to other ontologies like the GIS&T BoK.

It is however important to stress the fact that the Living Textbook tool is generic and can be used for any topic or domain and different levels of education. One of the real benefits of a tool like the Living textbook is the possibility to link to other sources of knowledge, data and software.

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