Hybrid e-TextBook:

A Comprehensive Interactive Learning Environment

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Context -Why now

Nowadays, many teachers use e-TextBooks in smart classrooms, having specific expectations regarding e-TextBooks' functionalities.

Need - Why you

Advanced functionalities of an e-TextBook make it possible to act as an Interactive Learning Environment in smart classrooms that facilitates the teaching process.

Task - Why me

In this paper, we propose the novel concept of an EPUB 3-based Hybrid e-TextBook, a comprehensive ILE that meets the needs of twenty-first century teachers in smart classrooms.

Object - Why document

To that end, we map teachers' expectations of e-TextBook with functionalities of e-TextBooks as ILEs. Next we co-design an e-TextBook with teachers. Finally, we develop the EPUB 3-based Hybrid e-TextBook that connects learning content to smart devices in classrooms. We used semantic web techniques (e.g., Hybrid e-TextBook ontology, content annotations)

Findings - me

The evaluation results reveal that our proposed Hybrid e-TextBook is a comprehensive ILE that provide required teaching tools for teachers in smart classrooms.

Conclusion - you

Furthermore, the experts' observations together with the rate of students' motivation (81.1%) learning using our e-TextBook show an effective impact on the cognitive and motivational aspects of the desired learning outcomes.

Keywords: Hybrid E-TextBook; Interactive Learning Environment; Smart School; Semantic Web; Digital Publication; Linked Data

Introduction

An effective e-TextBook needs to be an effective learning tool that empowers students and facilitates their learning (Lau, 2008). In comparison with adults, a number of young students accepted e-TextBooks, and find it more engaging than its printed counterpart (SCHOOLS, 2013). The interactive features (e.g. read aloud, interaction with smart devices in smart classrooms) of so-called Hybrid e-TextBooks increase excitement about learning, feeling of participation, and lead to advances in word recognition, especially for the elementary students (Strout, 2010). Thus, educational authors and designers (e.g. teachers) of e-TextBooks for youngsters should focus on functionalities of Hybrid e-TextBooks that increase students' interaction, and collaboration. Indeed, teachers expect specific functionalities of Hybrid e-TextBooks as Interactive Learning Environments (ILEs) when teaching in smart classrooms.

Our research focuses on developing Hybrid e-TextBooks for second-grade elementary school students, and has two main research questions: Firstly, "How can digital publishing and semantic web technologies enrich e-TextBooks as ILEs?" Secondly, "Does our proposed Hybrid e-TextBook meets teachers' needs when teaching, focusing on cognitive and motivational aspects of learning outcomes?"

The remainder of this paper is organized as follows. In section 2, we provide background knowledge needed for our study as follows: (1) we review a number of research projects on ILE, (2) we discuss Hybrid e-TextBooks as multifunctional content containers, and (3) we review a number of semantic web techniques (e.g. ontology), in

order to represent learning content. In section 3, we provide a mapping between the teachers' needs of e-TextBooks, and the desired functionalities of e-TextBooks. Next, we explore the advancement of Hybrid e-TextBook by developing an EPUB 3-based prototype. Furthermore, we investigate the way learning entities can be represented within a Hybrid e-TextBook and how these entities can facilitate interaction with a smart classroom (e.g. light changes). We subsequently evaluate the prototypes in Section 4. Finally, we present our conclusions and a number of directions for future work in Section 5.

Background

In this section, we first review research efforts that aimed at identifying the requirements of ILE, and teacher-based functionalities of e-TextBooks (e.g. access to updated e-TextBooks for students anytime). Second, we review a number of research efforts related to e-TextBook and its functionalities. Thirdly, in order to facilitate search, reusability, and discoverability of e-TextBooks as ILE, we review the usage of semantic content representation and reasoning about learning entities and emotions within Hybrid e-TextBooks.

Interactive Learning Environment (ILE):

Seel (2012) defines an ILE as "a system built in software, sometimes with specialized hardware, designed to support teaching and learning in education. The interaction in the system can be between the learner and the system, the teachers and the system or between teachers and learners with each other using the system. An ILE will normally work over the Internet as well as on mobile devices such as smart phones."
Referring to the above definition of ILE, it is designed to support teaching and learning in education over the Internet and on mobile devices. Thus, an ILE can be seen as a

mobile learning environment with similar functional requirements. Furthermore, ability to promote a strong interaction among students and teachers, improving motivation, and flexibility of the learning process are functional requirements for categorizing mobile learning environments (Barbosa, 2013). Please note that, this research considers the functional requirements of mobile learning environment necessary for ILE.

In addition, Huang & Liu (2014) see interactive learning as a practical teaching theory to improve students' comprehensive qualities. Furthermore, it uses various cooperative methods to facilitate communication of students. They discussed several interaction models for classroom-based teaching such as game-based and multimedia presentations that raise students' innovative thinking, knowledge acquisition and creation.

In this context, Raiyn (2014) said that "the digital world gives teachers new ideas, strong content, plentiful pedagogy, and a connection to virtual schools in real-time." Teachers inspired a new mission for the new kinds of e-learning environments, which contribute to grow students as strong thinkers and novel problem solvers. They presented innovative interactive and cloud computing-based learning tools (i.e., Al Qasemi Academic College), for creating new ways of teaching, where the teacher and students have active participation in the learning process either verbally or physically. They defined a platform that fulfills the requirements of flexible interactive e-learning.

In addition, Sessoms (2008) said that combining interactive boards and Web 2.0 tools provides a global interactive window that allows teachers to teach in an ILE. They discussed that technological innovations transform the teaching and learning process with a movement for comprehensive programmatic change that reflects a transformation in teaching methodology to influence teaching pedagogy.

The abovementioned studies see each educational tool as an individual mean that needs to be used for interactive teaching and learning. While our approach see these tools as content that are served by one unified system so-called Hybrid e-TextBook focusing on teachers' need when teaching in smart classrooms.

E-TextBook: Multifunctional and Heterogeneous Learning Content Container:

Among different types of learning objects, books were always an essential medium. The use of e-TextBooks, in comparison with traditional books, enables teachers to effectively control the students' learning process and has fully changed their teaching approaches (McFall, Dershem, & Davis, 2006). In what follows, we describe a number of book-related definitions, and functionalities in order to clarify the term "Hybrid e-TextBook".

E-book: The definition of an e-book, as discussed by (Vasileiou & Rowley, 2008), contains both a static and a dynamic component: whereas the static component states that "an e-book is a digital object with textual and/or other types of content", the dynamic component expresses that "an e-book can have technology-dependent features that make it more interactive and dynamic than its paper counterpart". In the above context, it is worth mentioning that, EPUB 3 (IDPF, 2014) is a digital publishing format that is used for enhanced, interactive e-books. This publication format is based on HTML5, that brings many benefits such as HTML5's capabilities for rich media (audio and video) and interactivity (via JavaScript). EPUB 3 is a powerful format for both representing and presenting e-book and its content (Ghaem Sigarchian et al. , 2015), and makes it possible to integrate multimedia features and semantic annotations using RDFa (Hermanet et al., 2015) or microdata (Hickson, 2013).

(E-)TextBook: E-TextBooks can be seen as e-books that contain educational materials

and functions, and which can be used for educational purposes (Landoni, M., Diaz, 2006). However, the definition of e-TextBook often changes because of the development of technologies and the new applications of these technologies in education are progressing. For example, e-TextBooks are designed to promote various types of interactions that (1) allow the student to work according to his or her needs and level every time and everywhere, and (2) integrate all of the contents from existing TextBooks, and workbooks, while providing a multimedia learning environment (e.g., videos, virtual reality) (Jung, 2009).

Kroes (2013) selected a number of functionalities of e-TextBook based on interviews with students and publishers. Those functionalities are as follows: "*offline availability*", "*connectivity*", "*reflowable content*", "*navigation*", "*run out of browser*", "*platform independent*", and "*types of interaction*". Furthermore, he evaluated open standards such as EPUB 3, SCORM(Vossen & Westerkamp, 2006), iBooks(Apple Inc., 2013), QTI (Imsglobal.org), and Tin Can API (Rustici Software, 2012) to cover the aforementioned functionalities. The results show that the capabilities of EPUB 3 make it possible to meet most of the requirements among the others.

Nakajima et al. (2013) presented typical functionalities of e-TextBooks based on a literature review, gathering functionalities into the following seven categories: "*authentication*", "*copyright*", "*content representation*", "*related information*", "*additional information by learners*", "*learning support*", and "*restriction of content and platforms*". In addition, they made use of EPUB 3 to implement these functionalities. E-books can be presented in the form of applications or websites, or they can make use of electronic publication formats such as PDF or EPUB 3. Nakajima et al. (2013) compared these different approaches and concluded that the use of EPUB 3 is the most suitable and the most flexible to meet desired e-TextBook functionalities.

Nakajima considered the following criteria in the comparative: *representation (multimedia, interactivity), communication (server connections, access to other resources), usage (offline usage, add / modify information).*

Lin, Liu, & Kinshuk (2015) investigated the teachers' needs when using e-TextBooks, based on teacher interview results, and the literature review. To that end, 378 teachers were asked to complete the e-TextBooks perception scale (NUEPS). The results showed that the teachers' needs include the following three factors: "*to support teaching activities"*, "*to support reading and presentation)*", and "*to support learning activities and parental interaction)*". Selection, design, and development of e-TextBooks are based on curriculum outlines for use in teaching. Functionalities of e-TextBooks should cover the requirements of the curriculum outlines similar to the teaching process and guidance. In addition, the e-TextBook should integrate supplementary teaching explanations (e.g. answers for assignments), instructional multimedia functions, teacher-student interactions and overall support of learning records.

Hybrid (e-Text)Book: considering the above mentioned definitions, an e-TextBook brings opportunities for new teaching and learning experiences. One such experience may consist of having interactions with the physical environment when making use of a so-called "Hybrid Book". Anastasiades (2003) defines the term "Hybrid Book" as "the best combination of use of traditional printed books and multiple potentials offered by a virtual educational environment". Other work (Ghaem Sigarchian, De Meester, Salliau, et al., 2015) proposed to generalize the term "Hybrid Book" to a paper or digital book that extends into the "physical or digital realm". We assume that a Hybrid e-TextBook can either take the form of an e-TextBook that facilitates interaction with the physical and/or digital learning content, or that it can take the form of a paper TextBook that has been enriched using digital content. In this context, we would like to point out that a

Hybrid e-TextBook can also be seen as an interactive content container that serves both physical and digital learning objects, for instance through leveraging the Internet of Things paradigm.

Considering the abovementioned definitions and studies on technologies for creating e-TextBooks, we conclude that an e-TextBook needs to be a multifunctional and heterogeneous learning content container.

Semantic Representation and Reasoning

Semantic Web technologies aim to collect, structure, and recover linked data. Thus, it facilitates search, reusability, and discoverability of relevant learning objects (e.g., e-TextBook and its content). In what follows, we describe a number of WC3 Semantic Web standards (W3C, n.d.), that enrich content representation, and reasoning about learning entities and emotions in Hybrid e-TextBooks, hereby creating an ILE.

Resource Description Framework (RDF) (Klyne, G., Carroll, J. J., McBride, 2014) is a general-purpose framework for representing Web information, expressing data in a machine-understandable format. RDF in attributes (RDFa (Herman, I., Adida, B., Sporny, M., Birbeck, 2015) adds a set of attribute-level extensions to (X)HTML documents, with the goal of including RDF data inside these documents. Terse RDF Triple Language (Turtle) (Beckett, D., T. Berners-Lee, T., E. Prud'hommeaux, E., Carothers, 2014) is a serialization format for RDF. An RDF query language such as SPARQL (Prud'Hommeaux, E., Seaborne, 2008) is able to retrieve and manipulate data stored in RDF format. An ontology is "a specification of a representational vocabulary for a shared domain of discourse, definitions of classes, relations, functions, and other objects" (Gruber, 1993).

Enrichment of HTML pages of e-TextBooks by using RDFa makes learning content machine-readable, and discoverable, thus facilitating the execution of queries against

this content. In addition it allows for interlinking learning content related to a specific learning subject for effective search. Learning material, including e-TextBooks and their content, often have general discoverability criteria such as (1) content (e.g., learning subjects), (2) structure (e.g., incorporation of content), and (3) context (e.g., geo-location) (Stojanovic, Staab, & Studer, 2001) . The usage of standard educational metadata such as LOM (Committee, 2002), facilitates discoverability and reuse of e-TextBooks and their content.

Furthermore, sets of vocabularies can be specified in ontologies. These sets of vocabularies can be used for extraction and reasoning purposes, with the aim of deriving new data. The new data can then be used for different goals, such as activating smart devices, or finding relevant content in an online sound repository. The Linked Data Fragments client and server (Verborgh et al., 2014) are two libraries for affordable and reliable querying of linked data with SPARQL.

BBC Curriculum Ontology (Liu, Mikroyannidi, & Lee, 2014) is made of a data model and vocabularies for describing UK national curricula that allows users to easily discover learning content. ALOCOM is an ontology designed for learning objects (Liu et al., 2014) . NERD (Rizzo & Troncy, 2012) is an ontology consists of mappings between the variety of named entity types. Schema.org (2011) is an ontology that is suitable for use in a variety of domains, including the description of events and creative works. It can thus be used to semantically enhance e-books. Onyx (Sánchez-Rada, J. F., & Iglesias, 2015) is a linguistic Linked Data approach for representing emotions that includes EmotionML(Schröder et al., 2011) vocabularies.

As we aim to connect learning content to smart devices through the usage of appropriate ontology, the aforementioned ontologies are not suitable for supporting different entities and their corresponding actions. Our proposed solution consists of a generic way to

represent the content of Hybrid e-TextBook as a comprehensive ILE. In particular we created an ontology that allows describing the relationship between learning items (i.e., particular item that is used to describe a learning object such as a video) on the one hand, and actions for activating smart devices on the other hand. In addition, our ontology allows mapping learning items, and emotions to corresponding sounds and colors (Nijdam, 2009). In addition, we make use of RDF for broadcasting learning items and emotions.

Hybrid e-TextBook Concept

Our research focuses on a Hybrid e-TextBook, an e-TextBook that facilitates interaction between the physical and the digital world, and where the interaction is enabled through the use of a generic data model. In this section, we first analyse the possibility of EPUB 3-based Hybrid e-TextBooks to act as ILE with a focus on teachers' needs. Next, we describe a prototype Demo Hybrid e-TextBook (2015) that uses a generic data model to facilitate interaction with devices in a smart learning environment (e.g., a classroom with smart educational aid).

Hybrid e-TextBook: a Comprehensive ILE

In "Background" section, we showed that a mobile learning environment has the characteristics and properties of ILE, thus we proved that a mobile learning environment is equivalent to ILE. Other works (Ghaem Sigarchian, et al., 2015) categorized the requirements of mobile learning environment into eight groups, linking each group to a particular set of e-TextBook functionalities. They identified a new e-TextBook functionality that is "*discoverability of an e-TextBook and its content"*. This new e-TextBook functionality targets the reuse of learning content. They proved that an

EPUB 3-based e-TextBook can act as a first-class mobile Learning Environment (we propose to read that research for detailed information about the mapping).

In what follows, we discuss the abilities of EPUB 3-based e-TextBook to cover teachers' expectations of e-TextBooks. To that end, we analyse (1) teachers' needs (Sessoms, 2008; Lin et al., 2015) when using e-TextBooks in classrooms, and (2) the typical functionalities of e-TextBooks identified by (Nakajima et al., 2013). Table 1 demonstrates how functionality of EPUB 3-based e-TextBooks as ILEs, covers the teachers' needs. Teachers' needs are as follows: "*exchange of teaching materials among teachers, and share notes and cooperative learning outcomes among students*", "*match with the learning diagnostic systems*", "*access to updated e-TextBooks for students a anytime*", "*analysis of assessments in-class*", "*supports for cooperative learning*", "*access to instruction and table of contents (TOC)*", "*obtain cues for reading progress*". In addition to the teachers' needs, we list the typical functionalities of e-TextBooks (Nakajima et al., 2013): "*content update*", "*connection (network, data transfer to server, Sensory data, Learning Management System (LMS) authentication)*", "*database management, study history*" , "*automatic quiz*" , and "*user interface (e.g. Table of Content (TOC))*". As can be seen in Table 1, the most used functionality of e-TextBook is the subset of *connection* that can be done through the use of the Internet or intranet from within e-TextBook. Networked e-TextBooks will typically be part of an LMS that authenticates the learner, and where the LMS is also able to take into account users' profile and learning plan information. To that end, e-TextBooks need to be able to send/receive data to/from a server via APIs and relevant applications. This functionality enables teachers and students to share or exchange data. As such, proper content can be shown based on the user role (e.g., teacher or student).

The next column includes the teachers' need regarding access to updated versions of e-

TextBooks and e-learning materials. In addition results of data exchange between e-TextBook and learning diagnostic system help teachers to adjust their teaching. Both of the aforementioned needs can be covered by the "*content update*" and "*connection*" functionality of e-TextBooks. Furthermore, an e-TextBook can automatically analyse the result of quizzes that are done in the classroom. The results can be sent to teacher, or the LMS of the school, where the e-TextBook of every student is connected. Thus, "*analysis of assessments in-class*" is covered through the "*connection*", "*database management*", and "*automatic quiz*". Indeed, this need refers to the capability of ILEs to authenticate multiple learners simultaneously working on the same platform. In addition, the EPUB 3-based format enables e-TextBook authors to provide a table of contents that makes teaching instruction accessible, with (1) a well-designed user interface for e-TextBooks, and (2) the availability of a network connection that makes it possible for learners to have their EPUB 3-based e-TextBooks communicate with other systems. This provides a way for collaborative and interactive learning, especially via smart device sensors.

The last need "obtain cues for reading progress" refers to the ability of tracking students reading and learning behaviour that is possible in EPUB 3-based e-TextBook using Tin Can API. Furthermore, EPUB 3 format supports "*reading order*" (W3C, 2011). Thus a well-designed user interface for navigating the learners complements this format.

Table 1. Match relevant functionalities of E-TextBook (Nakajima et al., 2013) to teachers' needs (Lin, Liu, & Kinshuk, 2015) while teaching

Teacher needs (Lin, Liu, & Kinshuk, 2015)	Relevant Functionality of e-TextBook (Nakajima et al., 2013)				
	Content update	Connection (network , data transfer to server, Sensory data, LMS authentication)	Study history, database management	Automatic quiz	User interface (e.g. TOC)
1. Exchange of teaching materials among teachers Share notes and cooperative learning outcomes among students		√			
2. Match with the learning diagnostic systems Access to updated e-TextBooks for students anytime	√	√			
3. Analysis of assessments in-class		√	√	√	
4. Supports for cooperative learning Access to instruction and table of contents (TOC)		√			√
5. Obtain cues for reading progress		√	√		

A Prototype Hybrid Book e-TextBook

Facilitating real-world interaction requires seamless collaboration between different learning components (e.g. learning entities) and devices in smart learning environments (e.g. lights). To create a prototype Hybrid e-TextBook, we used two suggested paper e-TextBooks by teachers that are used to teach 8 years old students in a number of schools in Belgium. Next, we co-designed the e-TextBook as ILE with the teachers. We aimed at influencing the digital and physical learning environment by manifesting different learning entities via the different human senses. The first e-TextBook is used for teaching animals' life concepts in winter (i.e. migrant, hibernation, and adapt), and the second e-TextBook is used for teaching night animals (e.g. owl, bat). We connect animals' properties to specific colors, for example, we map "migration" to blue-green (Poot et al., 2008), red for adapting (natural warm skin and cover), and blue for hibernation (cold and relax) (Taft, 1997). Furthermore, in the co-design sessions with the teachers, beside the usage of multimedia features (e.g. video of the animal life, read aloud), and interactive puzzle related to each animal, we were advised to use the color(s) that each night animal can distinguish at night (e.g. blue for owl, no color for the bat). Fig. 2 demonstrates a high-level overview of the Hybrid e-TextBook setup. As can be seen in Fig. 1, the educational author annotates the learning entities and emotions that are relevant to the desired interactions, before distributing the e-TextBook as an EPUB 3 file.

When the e-TextBook is taught by a teacher in a smart classroom, the annotated data are extracted and subsequently broadcasted (e.g. using socket.io (n.d.)) to all the smart device services via an e-reader (that is, an application for reading e-TextBooks). The smart devices need to be installed in the school network used by the Hybrid e-TextBook. If any of the smart devices are missing, then an alert can for instance be

shown in the pages of the e-TextBook. In addition, a specific service needs to be developed for each device. These services constitute a bridge between the Hybrid e-TextBook and the device. Furthermore, the data are interpreted by each device service, to determine the actions that need to be executed.

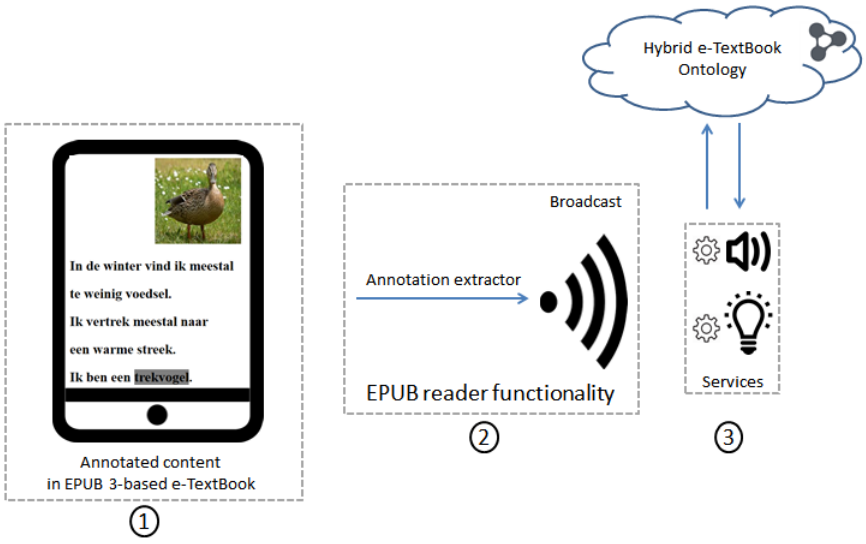

Fig.1. High-level overview of the Hybrid e-TextBook setup: (1) learning entities are annotated in the EPUB 3-based e-TextBook; (2) the e-book reader extracts these annotations from the e-TextBook and subsequently broadcasts these annotations; and (3) smart device services retrieve the broadcasted annotations, subsequently querying received data against the Hybrid e-TextBook ontology, and finally reasoning about configuration data (i.e., data needed to activate the smart devices.

Representation of Learning Entities and Emotions

It is the teachers' responsibility to see what tools will enhance cognitive development of students, in order to aid them in accessing and processing information (Sessoms, 2008). Thus, we see the educational author (e.g., teacher) of a learning object as the designer of the Hybrid e-TextBook. In particular, we see the teacher as the person who decides what interactive contents (e.g., read aloud, quiz) to be used. In addition the teacher decides what actions need to be taken. In that regard, the desired interactions a teacher wants to invoke must be inserted in the e-TextBook at the correct position. To

that end, we use HTML annotations using RDFa. These annotations define which changes are intended, and possibly, which action(s) should be performed. Figure 2 shows a possible annotation for a learning item. It shows how the word “migrate” is annotated with required attribute such as *typeof:”duck”* and *property= “life-winter”*.

```
<span vocab="http://uvdt.test.iminds.be/pub/hybrid/hybb#" typeof="Duck">
  <span property="life-winter" typeof="Migration">migration</span>.
</span>
```

Figure 2. Example of annotation for an entity

Triggering Actions Using Learning Entities

The way we define different attributes is described below. These attributes are extensible if needed. A teacher may decide to influence the classroom based on the different properties that a specific learning subject may have. By expanding the learning entities (e.g., animal) to their sub-entities (e.g., owl and bat), and more vocabularies such as “winter-life”, or “color-vision” we create a so-called Hybrid Book dataset that takes on the form of an ontology (Ontology, 2015). This dataset consists of learning entities, their corresponding data, and possible actions (e.g., “hasSound” as an action for a sound player and “hasColor” as an action for smart lights).

The proposed Hybrid e-TextBook needs to trigger the lights based on the annotated content. Thus, a service needs to bridge the gap between the Hybrid e-TextBook and the underlying APIs of smart devices. These services interpret the data to derive desired actions, by executing queries against our dataset. For example, when a story entity such as ``duck'' has been annotated in the text, the process executed is as follows:

- The e-reader extracts the annotated entity (e.g., *typeof:”duck”*) from the e-TextBook.

- The e-reader converts the data related to the annotated learning entity in RDF

format as it is shown in figure 3. The data is subsequently broadcasted to all connected devices (e.g., over the Internet or a local network).

```
    rdfa:usesVocabulary <http://uvdt.test.iminds.be/pub/hybrid/hybb#> .
_:1
    rdf:type <http://uvdt.test.iminds.be/pub/hybrid/hybb#Duck>;
    <http://uvdt.test.iminds.be/pub/hybrid/hybb#life-winter> _:2 .
_:2
    rdf:type <http://uvdt.test.iminds.be/pub/hybrid/hybb#Migration> .
```

Figure 3. Example of broadcasted data in RDF format.

- All connected devices receive the broadcasted data.

- We assume that each smart device has a service that listens for incoming data. As each smart device has its own functionality that needs to be adapted to the proposed solution. Thus, it is necessary to implement specific services for each of them. For example, the Philips hue lights have the functionality of changing the color of lights. The services has a query to decide what actions to take, based on a set of rules (e.g., *(:Migration rdf:type :Life-Winter, :hasColor :Blue-Green)*, or *(:Duck rdf:type :Animal, :hasSound :Duck)* stored in the dataset. In fact, the services query the received data against our dataset using the Linked Linked Data Fragments(Verborgh et al., 2014) server and client software. To that end, the LDF Server and Client are used for running SPARQL queries over Turtle data in our dataset. The resulting configuration data (data that are required to activate the smart devices) will for instance be formatted as ``:Action :hasSound :Duck" for the audio player and ``:Action :hasColor :Blue-Green" for the smart lights. Furthermore, to get the desired result (e.g., a relevant sound) from online resources such as (Spotify.com, n.d.), we need to have accurate search keywords. Based on the configuration data, the service of the sound player searches for a duck sound on Spotify.

- Finally, the light service sends the action to the hue lights to change the color of the lights, and at the same time, the sound service sends the action to the audio player to play the corresponding sound.

Authoring Hybrid e-TextBooks

Ideally, creating a Hybrid e-TextBook is facilitated by an authoring environment that makes it possible for teachers, educational authors, and publishers to indicate which learning items need to be annotated. Such an authoring environment is for instance discussed in, facilitating collaborative creation of enriched e-books using EPUB3, also enabling authors and publishers to design and create EPUB~3-based e-TextBooks(De Meester et al., 2014) with annotations.

Evaluation

In this section, we describe the evaluation of our prototype EPUB 3-based Hybrid e-TextBook to answer the research questions: (1) *"How can digital publishing and semantic web technologies enrich e-TextBooks as Interactive Learning Environments?" (2) "Does our proposed Hybrid e-TextBook meets teachers' needs when teaching, focusing on cognitive and motivational aspects of learning outcomes?"*

To answer the first question, we provide a qualitative evaluation as follows:

- **Coverage of the ILE requirements using Semantic Web***:* As our e-TextBook is based on EPUB 3, it is able to cover the desired functionalities of e-TextBooks. The usage of semantic web technologies such as (1) representing learning items and entities by creating the Hybrid e-TextBook ontology, and (2) querying against this ontology, makes the e-TextBook and its content

machine readable and discoverable. Using RDFa and Schema.org, allows users of such e-TextBook to access and reuse of linked learning content.

- **Sustainability and Interoperability of digital artefact***:* This aspect can be achieved by following standards, making the artifacts sustainable. All technologies used in the implementation of our Hybrid e-TextBook are based on open standards (e.g., e.g., EPUB3 format for e-book, Turtle format for data exchanges between different implementation platforms). Capabilities of such e-TextBook such as, "data transfer to servers", and "connecting to networks" allows for interoperability between different smart devices, thus preventing "reinventing the wheel" in future research.

- **Teacher-centred view**: This key aspect refers to involving educational authors (e.g., teachers) to easily design their desired ILE. Thus, they can apply their own preferences in terms of interactive learning content (that is, they can transfer teaching goal to the student through the use of varying types of interactions). Furthermore, the proposed Hybrid e-TextBook can be read on mobile devices coming with support for an EPUB 3 reader such as Readium (Readium.org, 2013), which is currently the reference EPUB 3 reading environment. In addition, it facilitates the usage of heterogeneous types of content for teachers, because they do not need to setup a number of different content in their teaching screen (e.g., interactive whiteboard) via proprietary teaching software's such as Activinspire (n.d.) or Silverlight (Michael Kozlowski, 2013).

To answer the second question, we conducted a user study. In Augustus 2015 we invited teachers to use the hybrid e-TextBook in a course we would create together with

them. We made an infographic and distributed this invitation via social media channels of iMinds, a Flemish research institute. In total 6 teachers from 3 different schools participated and 126 children in the second year of elementary school were observed. In 5 out of the 6 classes, the hybrid e-TextBook was used to teach about animals. In the sixth class, the teacher used traditional learning methods to teach her pupils about the same topic. Two iMinds researchers observed the teachers using the e-Textbook and also the teacher who taught her children with classical methods. In this way we could see if there are differences in motivations, attention, engagement, and collaborative learning between the different classes. After every course the children had to take a test, in this way we could also study if there are differences in the results between children who were taught about the animals with and without the hybrid e-TextBook. Also, the children who followed a course with the hybrid e-TextBook (n=106) had to fill in a Smiley o' meter (Read & MacFarlane, 2006), a Lickert scale (1= not like at all – 5=like very much) with smileys to express their enjoyment. After every course, the teachers were interviewed about their experience and about the potential of the hybrid e-TextBook. We made our observation keys and interview guide based on 14 key elements for evaluation of interactive learning systems created by Reeves & Hedberg (2003). This way we were sure to cover issues about technical issues (Visibility of system status, Error prevention) as follows: "*user-friendliness (error recovery and exiting, navigation support, help and documentation, message design)*", "*layout related (consistency and standards, aesthetics)*", and "*pedagogical content (match between system and the real world, interactivity, learning design, media integration, instructional assessment, resources)*".

By means of the observations and the Smiley o' meter (Figure 3), we can state that the majority of the children display a positive attitude towards the hybrid e-TextBook,

which suggests that they would be motivated to learn by means of this type of e-TextBook. According to the experts' observations, they were enthusiastic during the course. In addition, they were paying attention and were motivated to answer the questions of the teacher about the content of the hybrid e-TextBook.

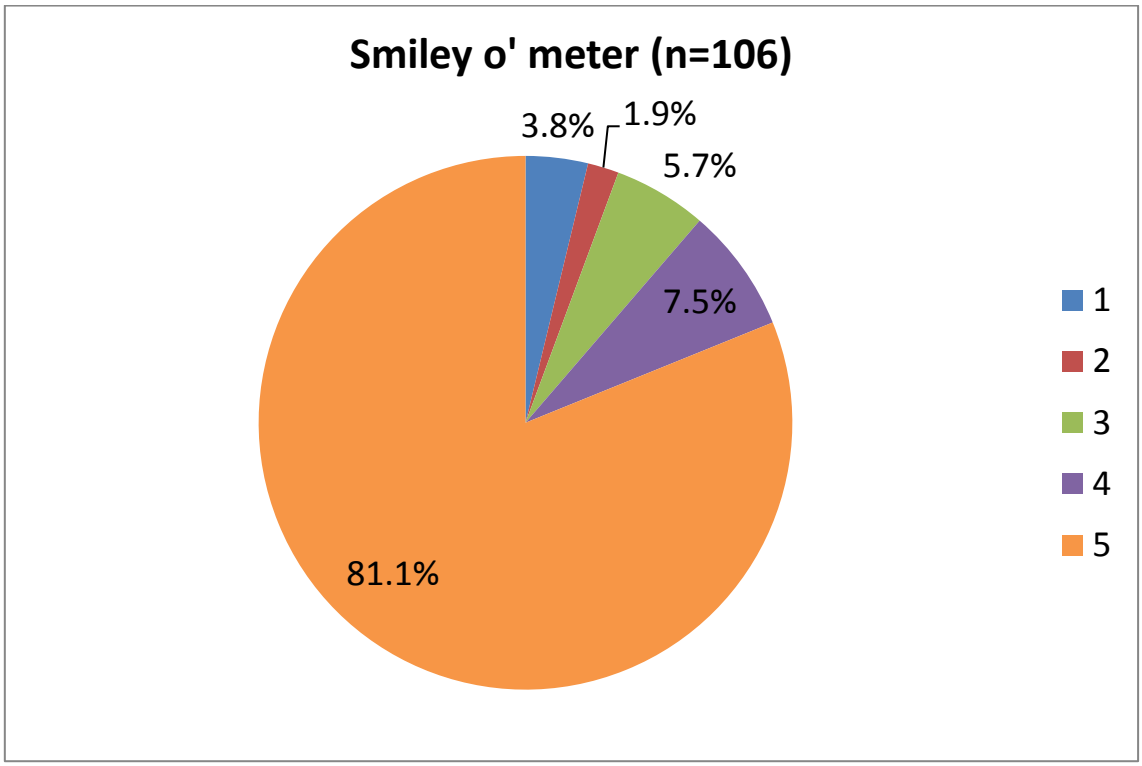

Figure 3: Results of the Smiley o' meters in the classes where the hybrid e-TextBook was used

81,1% of the children thought that the course with the hybrid e-TextBook to be a lot of fun to join. The results of the tests showed that the children mixed up similar animals, for instance a goose and a duck. Also, we divided them into groups based on their behavior during winter time. Some pupils mixed up between the animals of one group, for instance, both an owl and a rabbit get a thicker coat. When we compare the results of the tests of the pupils who made a test after a course by classical school methods, it is remarkable how many spelling mistakes they make. They also mixed up animals with the same behavior during winter time. Some of the children in the class who were

taught by traditional learning methods wrote down the same animal while it was explained that every animal is mentioned once. During the observations it was perceived that the children payed much more attention to the course with a hybrid e-TextBook. The children in the class who were taught about animals by means of a paper handbook and a PowerPoint the teacher made by herself, were more distracted. Data from the observations seem to suggest that children who are taught a course with a e-TextBook pay more attention during the course and they remember the spelling of the animal names better. This finding was confirmed by the teachers afterwards. For further research it would be interesting to do more tests on both groups to see if there are differences in remembering the course on the long term between children who were taught the lesson with an e-Textbook and the children who were taught the course in a more traditional way, because now the test took place after each course.

During the interviews with the teachers, it also became obvious that they like teaching with the hybrid e-TextBook. They especially like the combination of the various media (e.g., video, pictures, sound, and lights) about the same content. They are convinced that this combination will help children remember the content of the course easier. We asked the teachers to give scores to all the functionalities. Video is the most preferred function, while a picture of a map is less preferred (Figure 4). Furthermore, it is an easier way to use a hybrid e-TextBook instead of different content viewers (media player, a number of tabs in a browser, adobe PDF reader, etc.) and an application for connecting to educational aid devices such as interactive whiteboard, or smart devices. For teachers a hybrid e-TextBook can save their time. During the test, the lights changed according to the type of animal on the screen. Teachers believe this helps children to remember which type of animal every beast belongs to. As a target group, all the teachers say that this concept can be used for all children of elementary school if

you adapt the content.

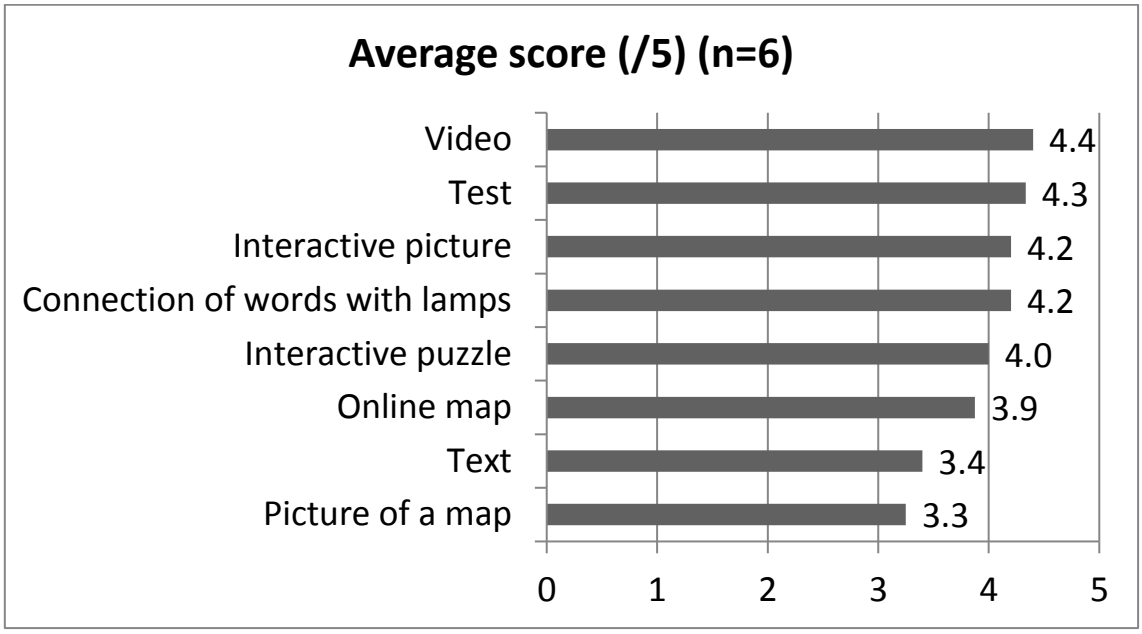

Figure 4: Average score for the different functionalities given by the interviewed teachers.

We also asked the teachers to rate the functionality as a help for individual or collaborative learning and they all agreed that, any functionality is useful for collaborative learning. Some of them, for instance "*Text*", can be used for individual learning moments as well. At the end of every interview, we asked teachers for potential other functionalities. One was to "*email yourself*" notes you make at the end of the course directly from within the e-TextBook. Every teacher thinks this would be interesting. Only one person said they would not email it to her, but rather save it as a part of the hybrid e-TextBook for the next time she will give the course. Another potential function is a "*read aloud*" functionality, which all teachers like for students with reading or language problems. In other words, this is not necessary for every pupil. One suggestion for a potential other functionality was to start with an overview of all the animals on one screen, a kind of table of content but by means of pictures. One teacher gave the suggestion to end the hybrid e-TextBook with a summary of the course

and present all the animals with the matching keywords.

We do have to remark that technology still is a big threshold for teachers. They are afraid that the technology will let them down and they will have to improvise. In order to make teachers feel comfortable using technology in their classrooms, it is important to involve teachers during similar future (technological) research projects.

Conclusions and discussion

In this paper, we reviewed ILE, e-TextBooks, and the way Semantic Web and digital publishing technologies can enrich e-TextBooks as ILE. Furthermore, to better understand the coverage of teachers' need, by functionalities of EPUB 3-based e-TextBooks as ILEs, we presented and discussed a mapping between the aforementioned needs and functionalities. In addition, we developed a proof-of-concept. The evaluation results reveal that the proposed Hybrid e-TextBook is a comprehensive and unified ILE, because it is capable to serve all functional requirements of ILE by (1) taking advantages of Sematic Web techniques such as querying learning items against the Hybrid e-TextBook ontology, and linked-content using schema.org and RDFa, and (2) serving heterogeneous types of learning content in a unified ILE that meets teachers' needs during teaching process in classrooms. In addition, the user evaluation revealed that the usage of the Hybrid e-TextBook in classrooms seemed to increase students' motivations and cognitive learning.

We can identify a number of directions for future research. First, user-friendly authoring tools are needed that allow for easy creation of e-TextBooks with widget support. Researchers have already taken steps in this direction (De Meester, 2014). Second, user-friendly authoring tools are needed that make it possible to easily add metadata, for

reasons of interlinking and discoverability. Finally, we will investigate techniques to create adaptive e-TextBooks with support for automatic content update features, and where these e-TextBooks are complementary medium for an LMS such as Moodle (Moodle.org, 2014).

References

Activinspire. (n.d.). Retrieved November 2, 2015, from https://www.prometheanworld.com/products/software-solutions/activinspire

Anastasiades, P. S. (2003). The Future of the Book, the Book of the Future (pp. 246–247). IEEE. doi:10.1109/ICALT.2003.1215066

Apple Inc. (2013). iBooks Asset Guide 5.1 Revision 2. Retrieved from https://itunesconnect.apple.com/docs/iBooksAssetGuide5.1Revision2.pdf

Barbosa, E. (2013). A Requirements Catalog for Mobile Learning Environments. *Proceedings of the 28th Annual ACM Symposium on …*, *55*(16), 1266–1271. doi:10.1145/2480362.2480599

Beckett, D., T. Berners-Lee, T., E. Prud'hommeaux, E., Carothers, G. (2014). RDF 1.1 (2014), Turtle Terse RDF Triple Language W3C Recommendation. Retrieved from http://www.w3.org/TR/turtle/

Committee, I. L. T. S. (2002). *Draft Standard for Learning Object Metadata (LOM) IEEE 1484.12. 1*. Retrieved from http://129.115.100.158/txlor/docs/IEEE_LOM_1484_12_1_v1_Final_Draft.pdf

De Meester, B., De Nies, T., Sigarchian, H. G., Vander Sande, M., Van Campen, J., Van Impe, B., … de Walle, R. (2014). A digital-first authoring environment for enriched e-books using EPUB 3. *Information Services & Use*, *34*(3-4), 259–268.

Demo Hybrid e-TextBook. (2015). Retrieved from we will make the Hybrid e-TextBook available upon acceptance of this paper

Ghaem Sigarchian, H., De Meester, B., De Nies, T., Verborgh, R., Salliau, F., De Neve, W., … Van de Walle, R. (2015). Towards Making EPUB 3-Based e-TextBooks a First-Class Mobile Learning Environment (p. 10). Proceedings of the 10th International Conference on e-Learning.

Ghaem Sigarchian, H., De Meester, B., Salliau, F., De Neve, W., Logghe, S., Verborgh, R., … Schuurman, D. (2015). Hybrid Books for Interactive Digital Storytelling: Connecting Story Entities and Emotions to Smart Environments (p. 12). Springer.

Gruber, T. R. (1993). Technical Report KSL 92-71 Revised April 1993 A Translation Approach to Portable Ontology Specifications by A Translation Approach to Portable Ontology Specifications. *Knowledge Creation Diffusion Utilization*, *5*(April), 199–220. doi:http://dx.doi.org/10.1006/knac.1993.1008

Herman, I., Adida, B., Sporny, M., Birbeck, M. (2015). RDFa 1.1 Primer - Third Edition Rich Structured Data Markup for Web Documents. Retrieved from http://www.w3.org/TR/xhtml-rdfa-primer/

Hickson, I. (2013). HTML Microdata. Retrieved from http://www.w3.org/TR/microdata/

Huang, M., & Liu, Y. (2014). Operation Models of Interactive Learning, (1), 256–260.

IDPF. (2014). EPUB 3 Overview. Retrieved from http://www.idpf.org/epub/301/spec/epub-overview.html

Jung, S.-M. (2009). Leading Future Education: Development of Digital Textbooks in Korea. *12th UNESCO-APEID International Conferrence Quality Innovations for Teaching and Learning*, (March), 1–13.

Klyne, G., Carroll, J. J., McBride, B. (2014). RDF 1.1 Concepts and Abstract Syntax. Technical Report W3C. Retrieved from http://www.w3.org/TR/rdf11-concepts/

Kroes, M. (2013). Creating the new eTextBook.

Landoni, M., Diaz, P. (2006). E-education: Design and Evaluation for Teaching and Learning. *Journal of Digital Information*, *3*(4). Retrieved from https://journals.tdl.org/jodi/index.php/jodi/article/view/118/85

Lau, J. (2008). Students' Experience of Using Electronic Textbooks in Different Levels of Education. *Scroll*, *1*, 1–7. Retrieved from http://fdt.library.utoronto.ca/index.php/fdt/article/view/4907/1768

Lin, Y., Liu, T.-C., & Kinshuk, . (2015). Research on teachers' needs when using e-textbooks in teaching. *Smart Learning Environments*, *2*(1), 1–17. doi:10.1186/s40561-014-0008-1

Liu, D., Mikroyannidi, E., & Lee, R. (2014). Semantic Web Technologies Supporting the BBC Knowledge & Learning Beta Online Pages. *Linked Learning Meets LinkedUp Workshop: Learning and Education with the Web of Data Co-Located with 13th International Semantic Web Conference (ISWC 2014)*.

McFall, R., Dershem, H., & Davis, D. (2006). Experiences Using a Collaborative Electronic Textbook: Bringing the "Guide on the Side" Home with You. *SIGCSE Bull.*, *38*(1), 339–343. doi:10.1145/1124706.1121448

Michael Kozlowski. (2013). Feature: Will The Future of Digital Publishing be HTML5, EPUB3 or Apps? Part 2. Retrieved from http://goodereader.com/blog/electronic-

readers/feature-will-the-future-of-digital-publishing-be-html5-epub3-or-apps

Nakajima, T., Shinohara, S., & Tamura, Y. (2013). Typical functions of e-textbook, implementation, and compatibility verification with use of ePub3 Materials. *Procedia Computer Science*, *22*, 1344–1353. doi:10.1016/j.procs.2013.09.223

Nijdam, A. N. (2009). Mapping Emotion to Color. Retrieved from http://hmi.ewi.utwente.nl/verslagen/capita-selecta/CS-Nijdam-Niels.pdf

Ontology. (2015). Hybrid-Book Ontology. Retrieved from we will make the demo Hybrid e-TextBook available upon acceptance of this paper

Poot, H., Ens, B. J., de Vries, H., Donners, M. A. H., Wernand, M. R., Marquenie, J. M. (2008). Green Light for Nocturnally Migrating Birds. *Ecology and Society*, *13: 47*(2), 1–14. doi:1

Prud'Hommeaux, E., Seaborne, A. (2008). SPARQL Query Language for RDF. W3C Recommendation. Retrieved from http://www.w3.org/TR/rdf-sparql-query/

Raiyn, J. (2014). Developing Online Course Based on Interactive Technology Tools, (July), 13–19.

Read, J. C., & MacFarlane, S. (2006). Using the fun toolkit and other survey methods to gather opinions in child computer interaction. *Proceeding of the 2006 Conference on Interaction Design and Children IDC 06*, (November 2015), 81. doi:10.1145/1139073.1139096

Reeves, T. C., & Hedberg, J. G. (2003). *Interactive learning systems evaluation*. Educational Technology.

Rizzo, G., & Troncy, R. (2012). NERD: A Framework for Unifying Named Entity Recognition and Disambiguation Extraction Tools. *Eacl 2012*, 73–76. Retrieved from http://newdesign.aclweb.org/anthology-new/E/E12/E12-2.pdf#page=83

Sánchez-Rada, J. F., & Iglesias, C. A. (2015). Onyx: A Linked Data Approach to Emotion Representation. *Information Processing & Management*, *9*(2), 16. doi:http://dx.doi.org/10.1016/j.ipm.2015.03.007

schema.org. (2011). Retrieved October 31, 2015, from http://schema.org/

SCHOOLS, M.-D. C. P. (2013). *LITERATURE REVIEW DIGITAL TEXTBOOKS* (Vol. 18). Retrieved from http://drs.dadeschools.net/AdditionalReports/LiteratureReviewonDigitalTextbooks.pdf

Schröder, M., Baggia, P., Burkhardt, F., Pelachaud, C., Peter, C., & Zovato, E. (2011). EmotionML--an upcoming standard for representing emotions and related states. *Affective Computing and Intelligent Interaction*, 316–325. doi:10.1007/978-3-642-24600-5_35

Seel, N. M. (2012). *Encyclopedia of the Sciences of Learning*. Springer Science \& Business Media.

Sessoms, D. (2008). Interactive Instruction: Creating Interactive Learning Environments Through Tomorrow's Teachers. *International Journal of Technology in Teaching and Learning*, *4*, 86–96. Retrieved from http://www.sicet.org/journals/ijttl/issue0802/4_2_1_Sessoms.pdf

Socket.io. (n.d.). Retrieved from http://socket.io/

Spotify.com. (n.d.). Retrieved November 2, 2015, from https://www.spotify.com/

Stojanovic, L., Staab, S., & Studer, R. (2001). eLearning Based on the Semantic Web. *Proceedings of WebNet 2001, World Conference on the WWW and the Internet*, (FEBRUARY).

Strout, K. (2010). Average, Below Average, And Above Average First Grade Students' Beliefs about Using E-Books to Activate Interest and Motivation in Reading, (May). Retrieved from http://rave.ohiolink.edu/etdc/view?acc_num=bgsu1269280187

Taft, C. (1997). Color meaning and context: Comparisons of semantic ratings of colors on samples and objects. *Color Research & Application*, *22*(1), 40–50.

Vasileiou, M., & Rowley, J. (2008). Progressing the Definition of "e-book," *26*(3), 355–368. doi:10.1108/07378830810903292

Verborgh, R., Hartig, O., De Meester, B., Haesendonck, G., De Vocht, L., Vander Sande, M., … de Walle, R. (2014). Querying datasets on the web with high availability. In *The Semantic Web--ISWC 2014* (pp. 180–196). Springer.

Vossen, G., & Westerkamp, P. (2006). Towards the Next Generation of E-Learning Standards : SCORM for Service-Oriented Environments. *Proceedings of the Sixth International Conference on Advanced Learning Technologies (ICALT'06)*, 1031–1035. doi:10.1109/ICALT.2006.1652622

W3C. (n.d.). W3C Standards. Retrieved October 31, 2015, from http://www.w3.org/standards/