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“Enabling Creative Learning Design: How HCI, User Modelling and Human Factors Help”

Workshop Organisers

George D. Magoulas, Patricia Charlton
Birkbeck College, University of London, UK

Diana Laurillard
Institute of Education, UK

Kyparisia Papanikolaou
School of Pedagogical and Technological Education, Athens, Greece

Maria Grigoriadou
University of Athens, Greece

https://sites.google.com/a/lkl.ac.uk/learning-design-workshop/
Preface

The interest in “Learning Design” (LD) as a focus of research began with the realisation that the constructivist pedagogical theories did not easily transfer to the practice of teaching. The emphasis on what learners were doing, and how to support their activities, was much less constrained by constructivism. This dependence on the context in which learning takes place required an approach to teaching based on design principles rather than pre-defined instructional sequences. Despite several attempts to develop “toolkits” or software to enable ease of entry into pedagogic design and support non-specialists in engaging with learning theories, existing e-learning systems and authoring tools have several limitations in respect of support provided and usability, and cannot accommodate the needs of teachers. Learning design is a creative process and tools are considered prescriptive and constraining and are often seen more as a hindrance. It is widely acknowledged that we need to do more to bridge the research/practice divide and create a genuinely interdisciplinary basis for representing learning design. Designing tools that can enable teachers to appropriately apply theory and practice, in more user centred way, to create learning designs may offer teachers experiences and tools that are more relevant to their needs.

This half-day Workshop aims at bringing together education, HCI and AI experts to discuss and share ideas about LD and AI-based technology to support content design, creation, sharing, re-use, modification and learning. Workshop papers explore new ways to place the designer requirements and the LD experience at the centre of tool development; discuss teachers-/learning designers-related information that should be captured in order to facilitate technology supported LD; look at how human factors considerations and knowledge engineering can be combined to inform the design of next generation LD environments and what kind of support teachers/designers need when using authoring tools in stand alone or collaborative mode; present experiences from implementing creative learning designs and user-centred models to support a more effective LD process.

July, 2009

G.D. Magoulas, P. Charlton, D. Laurillard, K. Papanikolaou and M. Grigoriadou
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# Table of Contents

Co-authoring personalised educational content: teachers’ perspectives
*Kyparisia Papanikolaou and Maria Grigoriadou*

1

Facilitating teacher/learning designer to formulate Learning Objectives (LO) using a Cognitive Skills based LO-Wizard in LAMS
*Spyros Papadakis and Ernie Ghiglione*

11

Agentic Instructional Design: Increasing the Learner’s Power to Exercise Personal Agency
*Russell T. Osguthorpe and Lolly S. Osguthorpe*

17

Applying creativity to Teaching in Computer Science: An exploratory learning course with LEGO Mindstorms robots
*Mikko Apiola, Jaakko Kurhila, Matti Lattu and Tomi A. Pasanen*

25

Digital Natives’ Learning and Teaching: the Amazonia Serious Game Scenario
*Ines Di Loreto, Abdelkader Gouaich, Fabien Hervouet, Guillaume Dalichoux, Alexandre Foucher, Panupat Patramol, Stefano Alessandro Cerri*

32

Zebra: A New User Modeling System for Triangular Model of Learners’ Characteristics
*Loc Nguyen*

42

Designing for Learning with Theory and Practice in Mind
*Patricia Charlton, George D. Magoulas, and Diana Laurillard*

52
Co-authoring personalised educational content: teachers’ perspectives

Kyparisa Papanikolaou and Maria Grigoriadou

Department of Education, School of Pedagogical & Technological Education, Greece
Department of Informatics & Telecommunications, University of Athens, Panepistimiopolis, GR 15784, Athens, Greece
spap@di.uoa.gr, gregor@di.uoa.gr

Abstract. In this paper we investigate how authoring activities of adaptive educational hypermedia content may cultivate e-learning content development skills, and promote reflection on learning design issues. Developing content for adaptive educational hypermedia systems is a demanding task that engages authors in self-explanatory activities and deep investigation of resources that correspond to learners’ multiple profiles and confront to specific learning design principles implied by the authoring tool. In this paper we present an empirical study where teachers worked in groups and used INSPIRE Auth to author content for INSPIRE and review content developed by peers. The strategies they used, the benefits they recognised and the difficulties they faced in this process, are described. The possible implications for extending the design of INSPIRE Auth are briefly discussed.

Keywords. Authoring tools, personalisation, adaptive educational hypermedia, knowledge representation, peer review

Introduction

Authoring tools aim at decreasing the cognitive load involved in various design steps of a learning environment. To this end, authoring tools explicitly represent the design of the learning environment and guide authors in controlling its main functionalities. Especially, in an adaptive hypermedia system, a final product of the authoring process is the internal representation of knowledge and information in a special form that is understandable and manageable by the system [1]. Authoring content for adaptive hypermedia educational systems is a quite demanding task, where learner modeling and adaptive functionalities of the system should be also considered. The development of authoring tools for personalised learning is a well developed research area that has already produced a variety of approaches for specifying and prototyping software solutions and content authoring [2] [3]. Main challenges, especially in the area of technology enhanced learning and learning design, remain the pedagogically sound development of designs and the teacher-practitioners’ engagement in the learning design process [4] [5]. Existing authoring tools have several
limitations in assisting teachers understand the implications of learning theories when designing instruction [6].

In this paper, we argue that the authoring process itself, might prove a useful learning experience for cultivating skills for learning design. Authors using an authoring tool, learn about the domain knowledge by designing instruction for their learners [7]. Thinking about the appropriate content and assignments, authors engage in self-explanatory activities and as a consequence, better learning results are obtained. It is also suggested that through engaging learners more systematically in authoring their own works they [8] (a) develop critical-thinking skills as authors, designers and constructors of knowledge and (2) learn more for the process than they do as knowledge recipients. In the SimQuest project [9] students work on activities that involve authoring domain models, whilst AnimalWatch tutor [10] is an authoring tool for students for authoring arithmetic word problems for their peers.

In the research presented in the paper we investigate the authoring process of adaptive educational hypermedia systems and particularly the content authoring process from teachers’ perspective. Adaptive content authoring is approached as an opportunity for cultivating skills for designing e-learning content, and promoting reflection on learning design issues such as the importance of learning activities in actively engaging students, or the need to provide a learning workflow to support effective learning. An empirical study has been conducted where an authoring environment was used for learning by doing. Teachers, that were also students, worked in groups in order to develop content for INSPIRE and used the INSPIRE Auth tool to author the content and review content developed by peers. Teachers’ strategies and perspectives on the particular learning design approach are investigated and implications for the design of the authoring environment are discussed. Preliminary results provide evidence about the potential of the content authoring process in cultivating learning design skills.

The paper is structured as follows. In Section 2 we investigate the range of necessary skills for authoring content. Then in Section 3, we present the authoring tool INSPIRE Auth and several functionalities that guide the authors through the authoring process based on the learning design implied by INSPIRE. The empirical study and preliminary results are described and discussed in Section 4.

1. Authoring content for adaptive educational hypermedia

The domain model of an AEH is usually represented as a network of domain concepts [1]. The concepts are related with each other forming a kind of semantic network which represents the structure of the subject domain. Thus, developing the domain model of an AEH system demands the identification of the domain concepts and their interrelations, i.e. the knowledge space needs to be structured. Moreover, content pages need to be designed for the domain concepts and linked to form a network of hypermedia pages with educational material, i.e. the hyperspace needs to be structured and linked with the knowledge space. The above processes are usually guided by the design of the AEH system.

As far as the content authoring process is concerned, first of all, authors need to modularise the content into reusable educationally meaningful elements (allowing the system to re-use them under different contexts and learners’ profiles) and design the hypermedia representation. To this end, the author needs to determine the learning
outcomes, analyse the content and modularise it into primitive components (concepts) which reflect the main topics of the domain and are physically and conceptually connected and interrelated. Then, the author needs to develop educational material for the domain concepts. In this process the author should take into account that the content will be used by a variety of learners. Thus, the author should develop educational material for the domain concepts in multiple formats and present information from multiple perspectives allowing those with different, for example, knowledge level or style, accomplish learning tasks in different ways. Critical characteristics of the educational material are the degree of interactivity and the learner control opportunities offered. To this end, skills on using or developing content for the Web are helpful, including information retrieval and designing activities using multimedia representations or computer simulations.

2. INSPIRE.Auth: authoring adaptive content

INSPIRE [11] offers personalised courses and support to learners by offering adaptive navigation advices based on learners’ individual characteristics (adaptive navigation support technique) and personalised versions of the educational material pages with alternative sequencing of the modules involved based on learners’ learning style (adaptive presentation support technique). The notion of learning goals that learners select to attain is used in order to build a hypermedia structure that provides an overview of how the relevant content fits together. Learners are invited to interact with the educational content provided for a goal in order to gradually [12] (a) speculate on newly introduced ideas by answering to introductory or self-assessment questions, following instances of the underlying concepts and real-life analogies, studying the theory, (b) become able to apply the underlying concept to specific case(s) by undertaking experimentation activities, working with computer simulations or microworlds, studying hints on the theory that concentrate on specific outcomes, solving small problems, (c) find a new generality, principle, procedure by accomplishing specific tasks in the form of small projects.

INSPIRE.Auth supports authors to use the authoring cycle as a conceptual framework for thinking about the structure and content of the domain knowledge based on the learning design implied by INSPIRE. The aim is to provide authors with a design approach for building a hypermedia perspective of the domain taking into account learners’ needs and preferences. Instructors and learners are authors in INSPIRE.Auth with different rights.

A form-based functionality has been developed to guide authors in the content authoring and evaluation process. Moreover, several visualisations of learners’ current state and progress support instructors in identifying students’ needs, preferences and strategies, and accordingly evaluate or revise the content. The authoring tool offers different functionalities to instructors and learners. They are both allowed to develop their own content following a specific learning design. However, instructors have full access to the content of INSPIRE, whilst learners are able to update and delete only their own content. Moreover, both are allowed to preview and evaluate content developed by peers. To this end, a peer review functionality is provided through which authors are allowed to (i) act as reviewers of educational content, submitting a special review-form, (ii) receive reviews of their content and revise it accordingly.
Currently, INSPIREAuth supports authors through the different stages of creating content for an AEH system [1] (a) structuring the knowledge, i.e. the domain model, (b) structuring the hyperspace, i.e. a network of hypertext pages with educational material, (c) connecting knowledge with educational material consisting of multiple representations that match learners’ varying needs and styles. Several tools and forms are provided to support authors in designing content based on the instructional framework of INSPIRE and define specific parameters of system adaptation [13].

**Structuring the knowledge.** The domain model of INSPIRE consists of learning goals and concepts. The domain model is a natural framework for goal modelling which is simply a target subset of domain concepts to be learned; learning goals are composed of a sequence of elementary sub-goals called layers each one composed as a set of concepts to be learned. Thus, the knowledge space is formed by a set of learning goals and concepts. Concepts are related to each other through prerequisite links and grouped in layers from the more general ones to the more specific. INSPIREAuth offers a variety of tools and forms for authoring and structuring the components of the knowledge space (goals, concepts) such as the tools for goal and concept management (see Figure 2), the forms for goal and concept authoring.

**Connecting knowledge with educational material.** The enhanced concept-based hyperspace approach [1] is used for connecting the knowledge space with the hyperspace forming the information space. Following this approach, multiple pages describing the same concept are connected to this concept in the information space and hyperspace. Each concept has a ‘hub’ page in the hyperspace which is connected by links to all educational material pages related to this concept (the same stands for the goals; the goal introductory page is connected by links to all concept ‘hub’ pages related to this goal). In the case of INSPIRE, each outcome concept is associated with: (a) an introductory page presenting the scope and learning objectives, (b) three types of educational material pages which correspond to the Remember, Use and Find levels of performance [12] (consist of a variety of knowledge modules: activities, examples,
exercises, assessment questions), (c) an assessment page, and (d) a summary page. This way, a role is assigned to each page link distinguishing several kinds of connections between concepts and pages and supporting system adaptation. For example, INSPIRE distinguishes the level of performance that a page supports and graphically annotates the educational material pages to reflect the progress of a learner.

INSPIRE Auth offers specific forms for authoring different types of content pages that correspond to alternative levels of performance. These forms prompt the author (a) what should be entered in textboxes that correspond to appropriate knowledge modules of multiple types such as examples, activities, assessment tests, and (b) how these pages or modules should be metadocumented through a set of metadata (general, pedagogical and technical) in order to support copyright issues, reuse of material, and the adaptation mechanism.

Thus, authors are guided in linking the knowledge with the hyperspace: they are stimulated to define a conceptual structure for each goal and the corresponding educational material pages for each concept (see in Figure 1 tools for content pages administration). Finally the functionality of the Information space structure preview illustrated in Figure 2 provides a graphical representation of the information space aiding to support learners link the knowledge with the hyperspace.

Evaluating students’ current state & progress. Teachers are provided with information about learners’ profile (learning style & knowledge level on the domain concepts) and multiple representations of interaction data reflecting their global activity compared to the model suggested by the tutor, learning trails, and progress. These representations aim at providing interpretative views of learners’ learning behaviour and support teachers in acquiring a comprehensive image of learners’ work, performance, interests and needs [14].
Figure 3. Mirroring learner’s interaction. The screenshot illustrates learners’ interaction with the content of a learning goal during a time span of 27 minutes. The data available is divided in three subareas reflecting learners’ activity on: (i) the content of the domain concepts, (ii) the different types of pages and keeping notes, (iii) the Learner model and adaptation controls.

Designing for multiple learners’ profiles is a demanding task, and by providing access to students’ profiles, the aim is to support teachers in identifying learners’ state and progress and accordingly evaluate and revise the content. For example, in Figure 3, information is provided about a student’s interaction with the content of a goal. For each concept of the goal, the area (i) of Figure 3 illustrates: the time spent along with the semantic density of the resource provided by the tutor in the content metadescription, visits along with total number hits on the content, level of performance on different types of questions and the way this was evaluated (automatically by the system or learner defined). Accordingly, area (ii) of Figure 3 illustrates learners’ activity with the relevant educational material pages of different types along with the semantic density of the resource provided by the tutor.

3. Empirical Study

The study performed to investigate teachers’ perspectives about the usefulness of the content authoring process for designing learning using INSPIREAuth. To this end, we aimed at identifying teachers’ (a) strategies in the development of lessons for students of multiple profiles, (b) opinions on the benefits and restrictions of the authoring process, (c) perspectives on the peer evaluation process as a peer support opportunity.

In this study, 22 students (13 females, 9 males) of the MSc in Educational Technology organised by the University of Athens and the School of Pedagogical and Technical Education, participated. The students were attending the course ‘Lifelong learning and ICT’ during the winter semester of the academic year 2008-2009. The students of the particular MSc are preservice (10 students) or in service teachers (12 students) of a variety of disciplines such as language teachers, science teachers, engineer and computer science teachers. The particular group was considered appropriate for the evaluation of the authoring procedure and environment since most of them are experienced teachers working on the public or private education sector.
During the study, students had the double role of students learning about adaptive educational hypermedia systems in an e-learning context but also of teachers and domain experts reflecting on the authoring process and a particular learning design for distance learning. In particular, they worked individually and in groups in order to develop educational material following the learning design implied by INSPIRE and author the content using the INSPIREAuth authoring tool. They also evaluated their peers’ educational material. At the end, they completed a questionnaire evaluating their learning experience, the authoring and evaluation procedure. The forum of an e-class environment of the particular course was used as a helpdesk and a shared space for collaboration.

3.1 Method

Students worked individually and in groups undertaking multiple roles. They initially worked as domain experts developing educational material following a particular learning design. Then they worked as reviewers evaluating their peers’ solutions and the authoring experience (usefulness, support in authoring content). The study took place through the whole semester.

In particular, students’ work organised in three phases as follows.

1st Phase (duration: two months): Initially, students had to develop content for a goal of their choice. At this phase students collaborated in groups. They had to select two or three main concepts for the specific goal and develop multiple types of content for these concepts following INSPIRE’s design. They initially produced a printed version of the content. Then they used INSPIREAuth to author the content. The main guidelines were to develop material of high interactivity (using simulations, applets, microworlds), promoting learners to explore and investigate the main concepts of the domain knowledge.

2nd Phase (duration: fifteen days): Students worked individually for reviewing content developed by their peers. After the submission of the reviews, students completed an evaluation questionnaire about this learning experience.

Table 1. Evaluation Questionnaire of learners’ content development, authoring and reviewing experience

<table>
<thead>
<tr>
<th>Section A. Content development process</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Describe the way you used the authoring tool to enter the content in INSPIRE.</td>
</tr>
<tr>
<td>2. Which was the added value in this development process for a teacher or a student?</td>
</tr>
<tr>
<td>3. What was problematic or indifferent in the development process?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Section B. Authoring process</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Describe the procedure you followed in the content development process based on the learning design of INSPIRE, e.g. step by step (like resource collection, concept selection, page development, learning objectives posed), goal &amp; content selection criteria, content structuring, learning approach adopted etc.</td>
</tr>
<tr>
<td>2. Which was the added value in this authoring process compared to the development of printed content?</td>
</tr>
<tr>
<td>3. What was problematic in the authoring process? How you faced difficulties?</td>
</tr>
<tr>
<td>4. In which phases of the project you would need support and ideas exchange with (a) your peers (β) the teacher. Which communication tools would you use?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Section C. Peer review process</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Describe the procedure you followed in the peer reviewing process</td>
</tr>
<tr>
<td>2. Comment on the suggestion “Students as reviewers should support a high quality result that will impact the products of both learners, i.e. author and reviewer”; Do you agree?</td>
</tr>
<tr>
<td>3. I would prefer to take</td>
</tr>
<tr>
<td>※ initially the teacher’s and then my peers’ reviewing comments</td>
</tr>
<tr>
<td>※ initially my peers’ and then the teacher’s reviewing comments</td>
</tr>
<tr>
<td>※ reviewing comments by particular peers</td>
</tr>
<tr>
<td>※ the teacher’s reviewing comments</td>
</tr>
</tbody>
</table>
3.2 Data collection and analysis

The data collected during the study include: (a) messages posted at the forum of the eclass, (b) content & reviews developed by groups, (c) learners’ evaluation questionnaires. The evaluation Questionnaire was organised in three sections (see Table 1): (a) questions about the process of developing content based on the particular design, (b) questions about the process of authoring the content using the INSPIREAuth tool, (c) questions about the process of evaluating the content developed by peers.

Below we present an initial analysis of the questionnaires reflecting students’ strategies when developing content and opinions about the benefits and drawbacks of working on a particular learning design.

3.3 Results & Discussion

Strategies used through the development of content for students of multiple profiles. Different strategies in the authoring process of educational content for INSPIRE were identified based on students’ descriptions. Actually most students followed a number of similar steps. Alternative orderings have been observed constituting different approaches to the authoring process. Main steps of the authoring procedure consist: (a) resource exploration, (b) familiarization with INSPIRE and the learning design approach through the guidelines offered or a prototype – a goal example, (c) decide on the goal, main concepts and learning objectives based on the domain, the design specifications, students’ needs or knowledge, (d) content development focusing on multiple representations promoting learner involvement. They search for or develop microworlds that students may interact with, make and test their own hypotheses.

Different approaches can be summarised as follows:

- most groups explore multiple types of resources, in order to decide on the topic and main concepts, then they studied the design approach and collaborate to develop content based on the proposed principles,
- other groups first select the topic, and then try to reuse existing content matching the objectives of the proposed approach, such as microworlds, simulations, examples. Then select concepts and set learning objectives. They adapt the content based on the specific requirements. In this case the design approach, was used as a guide for adapting and organising the content,
- a few groups start from studying the design approach, then select topic and main concepts and develop or collect multiple types of content. The content is finally structured based on the design principles.

Analysing students’ answers we observed that argumentation inside the groups on the topic, the content structure, educational material, and the design principles, was stimulated by the authoring process. Critical thinking on learning design issues and students’ needs was also recorded. It was mainly focusing on the development of multiple types of content aligned with the students’ preferences and knowledge level, and of authentic activities that promote learner engagement and control. Main considerations in this process were (a) needs and preferences of the target group of students, and (b) the development of a stimulating learner-centered environment where learners work autonomously, interact with the content and control their learning.

Implications for the design of the authoring environment are investigated concern the support that might be offered at the authoring process level or at the development
level, aiming at allowing authors to share or collaboratively develop content, promote argumentation and ideas exchange on critical steps of the authoring process.

**Benefits for designing learning and restrictions of the authoring process.** Students reported as main benefits of the authoring process: (a) the granularity of the design approach for developing e-learning content, (b) the integration of multiple representations in a comprehensive structure, (c) the hypermedia content structure and the content modularity that demands authors to synthesize content to a meaningful whole giving a sense of how all the information fits together, (d) the requirements for developing content for distance learning and particularly e-learning, (e) the need to design for all taking into consideration students’ individual differences, (f) the need for resource exploration in order to develop multiple types of content.

The specifications of the design approach demanding the development of multiple types of representations, interactive e-content, stimulated ideas generation. Moreover, students suggest that this process cultivates skills for developing e-learning content and analysing digital media necessary for e-learning. It also enhances awareness on the content development process since it involves many parameters of content development that were ‘obvious’ such as the corresponding level of performance of each content page, the descriptions of assessment queries including feedback or weights that reflect the importance of each question, or the metadescriptions of the content including pedagogical parameters like the semantic density of the resources. They also report that the authoring process of personalised content guided them in organising and orienting their knowledge and ideas towards the students’ perspective.

However, several students, although acknowledge the importance of the experience of working on a particular learning design approach in improving their own design strategies, they also suggest that the need to adopt one particular approach was quite restrictive “demanding adaptation of the individual teaching approach to the particular one”. A representative comment was that this approach is ‘useful and restrictive’! They also suggest that the particular approach may support teachers in organising teaching even in the classroom. Students also characterised the authoring tool as a useful tool for teacher training.

Based on the above comments, an important implication for the design of the authoring environment is to introduce flexibility in the domain structure proposed, allowing authors to make their own decisions at particular steps of the learning design approach and reflect their own perspective.

**Perspectives on the peer evaluation process, needs and support offered.** The peer review process was also an interesting experience for students. They worked on the selection of evaluation criteria, and apply the criteria to provide an objective review. Students characterised the whole process quite supportive in cultivating evaluation skills that are necessary for the development or selection of appropriate content (‘The reviewer evaluates the peer work but also his/her own work’). Most students found it as ‘objective’ since it comes from peers sharing the same problems and objectives - just one student argue that she didn’t feel comfortable as a reviewer due to limited experience with the topic and the role. A main advantage of the review process was that it made them consider their student's perspective, since most of them reported that they ‘evaluate the content initially from a students’ perspective and then as a teacher’. This is due to the double identity of the particular group being students but also teachers. They also reported that commenting on peers’ ideas requires consideration of how the ideas of others work and this process gives fresh ideas. Thus most of the students faced reviewing as ‘an oppporunity for self-assessment’ and helpful for both students.
As far as the type of support needed through the authoring process, most of the students report several problems. They mainly need help to resolve different issues at the content selection, content structuring or activity development stages and technical problems when working with INSPIRE Auth. In both cases, they found quite supportive the opportunity to co-author content working in groups, as well as the e-class forum which played the role of a helpdesk. They seem to appreciate a lot support coming mainly from peers but also from the teacher especially on learning design issues.

4. Conclusions and future plans

Teachers by authoring personalised content using the authoring tool that makes explicit the learning design requirements concerning content objectives and organization, elaborated on several learning design issues and made their own proposals. They characterised the process as quite demanding but also helpful in making them speculate on learners’ needs and elaborate on the subject matter.

Currently, the authoring tool supports teachers in understanding and evaluating the particular design. In our future plans is to extend the tool to allow teachers to construct their own designs and evaluation of these designs.

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Facilitating teacher/learning designer to formulate Learning Objectives (LO) using a Cognitive Skills based LO-Wizard in LAMS

Spyros PAPADAKIS\textsuperscript{a,1} and Ernie GHIGLIONE\textsuperscript{b}

\textsuperscript{a} Hellenic Open University, Greece
\textsuperscript{b} Macquarie University, Australia

Abstract. In this paper we will present the design of an intelligent service that supports non-specialists in formulating learning objectives through a “Cognitive Skill based Learning Objectives Wizard (CSLO-Wizard)”. Non-specialists teachers have problems writing objectives that describe the behaviour of the learner clearly. While the Learning Activity Management System (LAMS) is used worldwide as the world’s leading software for Learning Design, it does not provide support or assistance for teachers on how to write appropriate learning objectives. By using a CSLO-Wizard, teachers as learning designers would be able to overcome some of these issues.

Keywords. Learning Objectives, Learning Design, LAMS, Lesson Plan

Introduction

“Learning Design” (LD) is another viewpoint on practices traditionally referred to as lesson planning and course conducting. It lays emphasis on what teachers and learners do when design for learning and considers how to support better their activities for effective designs: creating designs for experiences that are motivating, enjoyable and productive for teachers and students alike.

One of the primary components of a course is the learning objectives. According to Kizlik “For most teachers, learning objectives are central to all lesson plans. That said, objectives that are used in education, whether they are called learning objectives, behavioural objectives, instructional objectives, or performance objectives are terms that refer to descriptions of observable student behaviour or performance that are used to make judgments about learning - the ultimate aim of all teaching” \cite{1}

Well-written learning objectives are the heart of any lesson plan. They provide a clear picture of the outcome or performance you expect as a result of the course, lesson, session, chapter, week or, lecture. It should be specific, concise, and, most importantly, observable or measurable.

Non-specialists encounter problems expressing objectives clearly, describing learner’s behaviour, or defining a measurable action in terms, of time, space, amount and/or frequency.

\cite{1} Corresponding Author: Spyros Papadakis, Hellenic Open University, 23 Sachtouri Str., 262 22 GR Patras, Greece; E-mail: papadakis@cap.gr
Although, there have been attempts to offer tools that enable ease of entry into pedagogic design and support non-specialists in engaging more with pedagogy and learning principles, existing LD-software has several limitations to accommodate the needs of practitioners. Teachers as learning designers look for authoring tools and intelligent support when developing their lesson plans, aims and objectives or asking question to improve critical thinking of their students and thus better prepare them to succeed in the world.

This paper is organized into three main parts. In the first we present the problem of supporting non-specialist to create effective learning objectives, explaining the design rationale. The second describe LAMS, the world’s leading software for Learning Design exploring its possibility to assist learning designers / tutors on how to write great learning objectives. After that, a Cognitive Skills based Learning Objectives wizard is proposed as a new service on LAMS and an example will be given of how the service is used, as far as its main operation is concerned.

1. Learning Objectives

A lot of pedagogy scientists (e.g. Mager, 1962) advocate the use of specific, measurable learning objectives that both guide designers during courseware development and aid students in the learning process. These instructional objectives, also known as "behavioural" and "performance" objectives can be applied directly in Gagne's second event of instruction, which is to inform learners of objectives [2].

Generally, learning objectives are competency-based as they designate exactly what students need to do to demonstrate mastery as part of a subject. They are brief, clear, specific statements of what learners will be able to perform at the conclusion of instructional activities.

The purpose of learning objectives is to: a) facilitate overall the course, session and activity development by encouraging goal-directed planning; b) inform students of the standards and expectations; c) provide a framework for evaluating student progress and d) make implicit the educational contract between teacher and students.

It is very common that many teachers used inappropriate “vague” verbs such as "know", "understand" or "learn about" to describe learning objectives. They are not measurable because there is no product involved. “How does one know if someone knows or understands something?” The performance objectives in most cases ignore an indication of standards and the conditions. Standards are measurable criteria (e.g. How often/well/many/much ...). Condition should be replaced with more specific verbs for a written indication of the behaviour using measurable or observable verbs.

This is the problem faced by Computer Science tutors at the Technological Educational Institute of Lamia, Greece. The data provided as the basis of this study was collected from LAMS sequences specially designed to provide distance learning opportunities for adults [3], who are Computer Science graduates, or graduates that use computers as a tool in their work. A total of sixty eight (68) lesson plans selected from twenty two (22) online courses were analysed. These were mainly in Computer Science, but there are also some interdisciplinary courses participated in the study investigating the learning objectives teaching Computer Science concepts.
Table 1. Frequency of inappropriately defined learning objectives in the analysed LAMS Sequences

<table>
<thead>
<tr>
<th>Learning Objectives (LO)</th>
<th>Observed N</th>
<th>usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>unsuitable verbs</td>
<td>39</td>
<td>57%</td>
</tr>
<tr>
<td>promote lower-order thinking</td>
<td>43</td>
<td>63%</td>
</tr>
</tbody>
</table>

Descriptive statistics showed that fifty seven percent (57%) of the learning objectives did not use a suitable verb. Approximately two thirds (63%) of the learning objectives aimed at engaging learners beyond simple reproduction of knowledge to higher-order thinking (Table 1). This is similar to an older study [4] which found that students have difficulties in assimilating modern learning theory concepts and applying them in practice when designing lesson plans that utilize such concepts.

Our findings are in line with other relevant literature that suggests students must do more than just listen: “They must read, write, discuss, or be engaged in solving problems. Most important, to be actively involved, students must engage in such higher-order thinking tasks as analysis, synthesis, and evaluation” [5].

Many tutors write what they desire to accomplish in delivering a learning activity (goals) instead of learning objectives. A key point is a set of well constructed learning objectives, the achievement of which contributes to the attainment of the goal.

1.1. Learning objective for Higher Order Thinking

A guide to Productive Pedagogies at the Department of Education of Queensland states that Higher-order thinking by students: “involves the transformation of information and ideas. This transformation occurs when students combine facts and ideas and synthesise, generalise, explain, hypothesise or arrive at some conclusion or interpretation. Manipulating information and ideas through these processes allows students to solve problems, gain understanding and discover new meaning. When students engage in the construction of knowledge, an element of uncertainty is introduced into the instructional process and the outcomes are not always predictable; In helping students become producers of knowledge, the teacher’s main instructional task is to create activities or environments that allow them opportunities to engage in higher-order thinking”.

There are different levels of thinking frameworks that inform the writing of objectives. A committee of colleges, led by Benjamin Bloom [6] identified three domains of educational activities:

- Cognitive: mental skills (Knowledge);
- Affective: growth in feelings or emotional areas (Attitude);
- Psychomotor: manual or physical skills (Skills).

Bloom’s Taxonomy of Cognitive Objectives is one of the most universally applied models providing a way to organise thinking skills into six levels, from the most basic to the higher order levels of thinking. Taxonomy is hierarchical; meaning that learning at the higher levels is dependent on having attained prerequisite knowledge and skills at lower levels [7]. The revised edition of Bloom’s taxonomy by Anderson has moved Synthesis in higher order than Evaluation [8]. Some consider the three lowest levels as hierarchically ordered, but the three higher levels as parallel.

Students are usually engaged only in lower-order thinking; i.e. they receive, or recite, or participate in routine practice. More complex activities still may involve reproducing knowledge when students only need to follow pre-specified steps and routines in which students do not perform some higher-order thinking.
2. The Learning Activity Management System (LAMS)

LAMS (the Learning Activity Management System) is a system for educators to author learning designs using a drag and drop interface, as well as run these designs with learners and monitor learner progress. Initial LAMS development began in 2002, and a live prototype was first demonstrated at the Valkenburg group meeting in Vancouver in February 2003[9]. It was subsequently trialled in a range of university and school contexts in 2003 and 2004, with the Version 1 release in December 2004 (LAMS Foundation, 2004), followed by the release of LAMS as open source software in 2005.

While LAMS was “inspired” by Educational Modelling Language (EML) and IMS Learning Design (IMS LD), its initial focus was on activity tools for learning design; not to serve as a reference implementation of EML or IMS LD. Although the initial development of LAMS attempted to implement IMS LD, a series of challenges meant that this was not achieved in the first version [9] [10].

Since it was released as an open source software, LAMS has been used in many educational sectors like K-12, vocational and corporate training as well as in Higher Education institutions worldwide. LAMS wide spread usage, along with the community of educators using LAMS (LAMS Community) has been awarded the IMS Learning Impact Gold prize in 2009.

LAMS until now does not provide support for teachers on how to write well good learning objectives. In the next session we describe the design of a new service that aim to help authors in defining good, clear, and concise learning objectives.

3. The Cognitive Skill Taxonomy based Learning Objectives Wizard

Within this context, a service is proposed that facilitates writing of learning objectives by learning designers and tutors with the aim to promote active learning and to create learning activities that would involve students creatively doing things and thinking about what they are doing.

A “Cognitive Skills taxonomy based Learning Objectives Wizard” (CSLO-Wizard) facilitates the development of appropriate learning objectives for a proposed educational experience.

CSLO-Wizard uses a two-phase process to create a set of learning objectives. In the advice phase, the Wizard first asks the use to select and edit a stem for a series of learning objectives (Figure 1). For example: After this activity, the learner will have . . . ; as general advice to learner. In the construction phase, the Wizard guides authors to construct a Learning objective (LO) statement [11] as an intended learning outcome that contains three parts: behaviour, conditions, and criteria. This is a four-step process performed to help the author creating learning objectives to:

Step 1. Choose a cognitive skill in one domain of a classification. For example Bloom’s Taxonomy [6], or Bloom's Revised Taxonomy [8].
Step 2. Choose an associated action verb that denotes an observable action or the creation of an observable product.
Step 3. Choose the condition under which the behaviour is to be performed. This specifies the circumstances (aiding or limiting), command, materials and directions (to assist or to make the action more difficult to perform) that the learner will be given to initiate the behaviour.
Step 4. Choose, how well the behaviour (author desire) to be performed (criteria) - to satisfy the intent of the behavioural verb. The degree of accuracy, a quantity, or a proportion of correct answers.

Figure 1. How to use the CSLO-Wizard to create a series of learning objectives

4. Conclusions

Research consistently has shown that traditional lecture methods, in which professors talk and students listen, dominate university classrooms. The reform of instructional practice in higher education should begin with faculty members' efforts to set learning objectives and activities promoting active learning [12]. Learning design tools like LAMS are able to help faculty, learning designers, developers, tutors and administrators to make real the promise of active learning and higher order thinking.

LAMS's CSLO-based wizard is promised to help in this direction. Future work focuses on the implementation of the CSLO-Wizard as an add-on to the FCK Editor to be available in all LAMS tools as well. Additionally, an evaluation study will be organised to get instructors’ feedback and gain insights about how the CSLO-Wizard helps addressing common problems encountered when writing objectives.

References


Agentic Instructional Design:
Increasing the Learner’s Power to Exercise
Personal Agency

Russell T. OSGUTHORPE a,1 and Lolly S. OSGUTHORPE b

a Center for Teaching and Learning, Brigham Young University, Provo, Utah, USA
b Provo School District, Provo, Utah, USA

Abstract. This paper describes a model that teachers can use to help students master intended learning outcomes while simultaneously helping students expand their own power of personal agency. The model depicts how the student’s desire for learning can increase as the frequency and significance of success increases. An illustrative case shows how the model has been used in a sixth-grade class to improve student performance and raise students’ expectations for educational success. Emphasis is placed on the role of online testing as a motivational tool to help students choose to learn.

Keywords. student motivation, learner success, online testing

Introduction

The design of instruction has typically centered on improving student performance on specific learning outcomes. Theorists have postulated that if learning materials are designed effectively, students will naturally perform at higher levels of mastery. Benjamin Bloom recommended “mastery learning” [1]. Robert Gagné suggested nine events of instruction, categories of learning, and task analyses [2]. Others asserted that following a systematic design model, such as the ADDIE model, effective instruction would more likely result [3].

Developmental psychologists and cognitive scientists challenged the instructional design theorists by claiming that such theories did not focus adequate attention on the unique needs of learners. They emphasized, for example, the necessity of understanding the learner’s thought processes rather than simply the instructional task itself[4]. Constructivists emphasized the centrality of how students make meaning and the need to design “student-centered learning environments” [5].

As the learning sciences has emerged as an interdisciplinary field embracing, as proponents assert, all aspects of the teaching and learning equation, the focus has remained on the learner as the central concern—how the learner acquires knowledge, what motivates the learner to learn, and how technology can help learners improve their performance [6].

1 Corresponding Author: 3810 HBLL, Center for Teaching and Learning, Brigham Young University, Provo, UT, 84604, USA; E-mail: russ osguthorpe@byu.edu.
Whether one adheres to theories in instructional design, cognitive science, or the learning sciences, the emphasis is on improving student learning by measuring performance on specified learning outcomes. Each of the theoretical orientations focuses on the needs of the learner—either how the student can be helped by well-designed instruction to perform better (i.e., the instructional design theorists), or how the environment surrounding the student can adapt itself to the needs of individual learners (learning sciences). One approach emphasizes the effectiveness of the materials given to the students, while the other emphasizes the unique abilities that each student brings to the learning situation, but both eventually arrive at the same destination—student performance on predetermined learning outcomes.

Although there is nothing wrong with specifying learning outcomes and maximizing efforts to achieve them, we assert in this paper that such focus falls short of what is needed to reach the ultimate goals of education. Society cannot view education only as a means of producing academic competence. The aim must be much broader. Competence for what purpose? Knowledge to benefit whom?

Helping students become more proficient learners is not enough. Education must lead to something more. And design models must aim at these higher purposes. We suggest in this paper that one such higher purpose of education is helping students to use their personal agency more effectively. Agency, as we speak of it in this paper, is the ability of a person to act in socially positive ways to accomplish a desirable goal—a goal that eventually benefits others. It is the individual’s power to choose the good or to yield to the good [7]. Personal agency has a moral component: all choices are not equally acceptable, a cognitive component—one cannot choose among alternatives that are unknown to the learner, as well as a motivational component—the student must desire to learn, and the more that desire grows, the more learning will occur. All of these are aspects of personal agency—the power to choose [8,9].

Neither instructional design theory [10] nor theory espoused by the learning sciences [6] is commonly used by teachers in K-12 classrooms. The theories are valuable for those who design curriculum that teachers use, but not for teachers themselves, first, because teachers have little time to create instruction from scratch and second, because teachers have little time to master theories like those that theorists in either field promote. Yet teachers are creating instruction daily. They are making decisions about how to help those in their class improve not only their academic performance, but to build their character as well [11]. To accomplish these goals, they seldom follow rigidly any instructional product the school adopts.

For a theory or model to be useful to K-12 teachers, it should possess the following characteristics:

- *Easy to learn and use* for the teacher and for the students,
- *Memorable*—a model that does not require frequent review,
- *Broadly applicable* to all types of learning outcomes,
- *Focused on caring relationships* between learner and teacher
- *Grounded in interdisciplinary research*, and
- *Aimed at the higher agentic purposes of education.*
1. The Three D’s of Success

During the past five years we have been developing such a model. Some might view it as a motivational tool. Others may see it as a technique to improve self-efficacy[12]. Still others may perceive it to be an outgrowth of the positive psychology movement[13,14]. Few would view it as an instructional design model or theory. In one sense, it lies underneath such theories. It does not prescribe to a designer or teacher how to craft a definition, select examples, and provide practice. Rather the model raises student and learner aims to something beyond the learning task at hand. We call it The Three D’s of Success. It is easy for students and teachers to learn, memorable, broadly applicable, leads to more caring relationships, is grounded in interdisciplinary research, and is aimed at the higher agentic purposes of education. Figure 1 shows the model.

![Figure 1. The Three D’s of Success.](image)

The first D (desire) in Figure 1 depicts the student’s intent to learn. How intent is the student to accomplish the goal at hand? What is the student actually thinking about? In an early study on the role of attention in learning, Bloom [1] showed that when time-on-task was measured, students who had been perceived to be the “slowest” learners were actually nearly as fast as the “fastest learners.” The problem was that the slow learners did not attend. They did not try. In our parlance, they lacked desire. They were not succeeding in the classroom because they did not expect to succeed. They were not imagining themselves experiencing succeed. They were not thinking about succeeding.

Students who lack the desire to learn are often the most difficult students for teachers to teach. The teacher cannot manufacture desire for the student. Some students cannot be coaxed into learning. When such students present themselves, the Three D’s model suggests that the teacher ask the student to make some decision—even in the absence of desire. This decision might be simply to take out a pencil and begin working, to complete an assignment, or to help a classmate. The important thing is to decide to act, and to talk about the decision—to voice it to the teacher or to other students. Once the student begins to initiate activity, the teacher helps the student become determined to succeed—even when the student is not accustomed to succeeding. This is the action part of the model—turning personal agency into actual performance.

The teacher then helps the student recognize success—regardless of how small the success might be. Once the student has succeeded, the student’s expectations grow. The student now knows that he or she can succeed at a task that was previously challenging—even a task that once appeared to be impossible. So expectations increase. And when expectations increase, the student’s desire to progress grows [15]. Personal
agency is at the heart of every step of the model. It appears most obvious in the Decision phase, but it flows through all parts of the model. Determination requires agency to remain engaged in the learning task. Expectations are agentic by definition. Raised expectations give rise to new decisions by the learner because now the learner has more options since increased competence breeds increased choices.

2. Using the Three-D’s Model in a Sixth-Grade Classroom

To illustrate how the agentic Three-D’s Model can help students raise their level of academic performance while expanding their power to exercise their personal agency, we will describe specific applications of the model in the co-author’s sixth-grade classroom. First we will explain how the model was used this past year to help students improve their reading and language arts performance. Then we will describe how the model was used in the class to help students use their own agency more effectively to master any learning outcome in the class.

Improving reading proficiency of sixth graders. During this past year the Three D’s Model was used in conjunction with the McMillan/McGraw-Hill Treasures Reading program [16]. At mid-year online computer testing became available for weekly student assessment. Figure 2 shows the mean number of students for four weeks scoring at the following levels on the online assessments: below basic, basic, proficient, and advanced levels of reading and language arts skills as defined by the

![Figure 2. Number of students scoring at each level of reading proficiency on mid-year and end-of-year online assessments.](image)

_Treasures Reading_ program online assessments. Note that on the four mid-year weekly assessments, 2 students scored below basic proficiency, while on the four end-of-year weekly assessments no students scored at that level. Seven students scored at the basic level, while only 2 remained at that level on the four end-of-year weekly assessments. Those scoring at the proficient level went from 6 at mid-year to 7 on the four end-of-year weekly assessments, and 5 more students scored in the advanced level at the end
of the year when compared with scores on the mid-year weekly assessments. In addition to administering the Treasures Reading weekly assessments, the teacher also administered on a monthly basis the online STAR Reading Test and on a weekly basis *Accelerated Reader* quizzes that corresponded to the *Treasures* stories [17,18].

### 3. Five Profiles of Student Success

We will now describe five students in the co-author’s sixth grade class during the 2008-2009 school year. Their pseudonyms are Suyan, Jane, Alan, Neal, and Becca. The co-author will describe the student profiles in first person.

Suyan is an English Language Learner (ELL) and was reading on a third-grade level at the beginning of the year. He had experienced ELL courses for three years and had tested out of them. Although he had above average intelligence, he did not turn in his homework or remember where he put his things. He had learned to tune out spoken English, and I had to ensure that he had heard what I had said, or he would just sit and do nothing throughout the day. Online testing at midyear revealed that Suyan was still performing below the basic level on the Treasures Reading assessment and had shown little improvement since the beginning of the school year. I had repeated conversations with Suyan about his lack of effort. Following these conversations, Suyan decided to read the passages carefully and understand the new vocabulary so that he could perform well on the online testing. He chose to retake the tests offered online until he experienced success. The more successful he became, the more his desire increased both in math and reading and language arts. At the end of the year, he tested at the advanced level on the Treasures Reading assessment.

Jane was reading at a fourth-grade level at the beginning of the year. Although she came from a home with two highly educated parents and high achieving siblings, she struggled in both math and reading, but wanted to be like her older sister and be in my pre-algebra math class for sixth graders. Although her scores did not merit inclusion in the math class, I told her she could try the class for one month, and then we could make a decision. Of greater concern for me was her reading level. When she experienced success in math, she decided to make the same effort in reading. With this increased effort, she experienced similar growth in reading as she had in math. Her mid-year reading level hovered between “below basic” and “basic,” but during the last quarter, her scores were consistently in the advanced level. At the beginning of the year, Jane had difficulty reading for comprehension. When she was required to pass the online *Accelerated Reading* quizzes before taking the Treasures Weekly Assessments, she read more carefully and practiced the comprehension skills taught in class. The online testing allowed her to become more determined and thus, experience more success.

Alan was extremely slow in completing assignments and tests. Always the last student finished, he took twice as long to read a passage as most other students and read below grade level. I encouraged fluency but decided that it would be more exciting for him to increase his comprehension scores so that he could see immediate success. He also wanted to be in the advanced math class. However, not only were his math scores low, but he had been in the low math group in fifth grade and had not covered all of the year’s curriculum. At the end of the sixth grade year, Alan tested in the 97th percentile in math and 94th percentile in language arts on the end-of-level criterion referenced tests. In reading, Aaron had scored at the basic level for months, but with consistent effort, he steadily improved and ended the year with 100% on the
final online *Treasures* test. Requiring 80% on the online *Accelerated Reading* quizzes motivated him to carefully read the passages for comprehension. The more he exercised his agency to attempt what once seemed impossible to him, the more determined he became to succeed in both reading and math.

Neal’s physical appearance was that of a third grader, reading two years below grade level. His father had been abusive to the mother, and Neal had witnessed the abuse. His mother, now divorced, had several health problems that negatively impacted the family. Neal was absent 23 days of the school year. He missed a lot of direct instruction, but was willing to try and make up what he could. At the beginning of the year, Neal usually scored at the basic level on the weekly assessments, but with consistent attendance and instruction the last two months of school, he ended the year at the advanced level. Online testing was especially helpful for me as a teacher to track his progress and allow him to make up missed tests and quizzes.

Becca transferred to my class after the first term was completed. Reading two years below grade level, she struggled with reading skills and needed extra help to complete assignments. She did not seem to grasp ideas or content quickly. She scored below basic or at the basic level in reading for several weeks, and required extra tutoring. We had a reading incentive program to read 7000 minutes by the end of the year. I told her I would prorate her minutes because she had not been in the class the whole year. She decided that she wanted not only to read 7000 minutes and qualify for the class party, but wanted to achieve the individual honor of 15,000 minutes and have dinner with the teacher. She completed the minutes required for the dinner and scored at the advanced level on the *Treasures* assessment. At the end of the year, Becca would come to me first and ask to retake a computer quiz if needed, because she was so motivated to understand. She was so excited to finally “get it” and have success.

4. Student Comments

I often talked about the Three D’s of Success in class and explained how students could learn to exercise their power of agency—how they could choose to learn. I taught the class to sing a song about the Three D’s. At the end of the year, when asked which songs they wanted to sing, *The Three D’s of Success* was their first choice. The following comments are excerpted from unsolicited cards and notes that students in the class wrote to me at the end of the school year:

- *Desire—Decision—Determination . . . Every time I feel it’s too hard or that I can’t do it, I always remembered those three words!*  
- *Thank you for teaching me the Three D’s. I will always remember them.* *Thank you!*  
- *The desire, decision, and determination for me to succeed was incredible!*  
- *I promise I won’t forget the Three D’s!*  
- *I truly am better at a lot of things. Desire, decision, determination, YES! I have success!*  
- *I will always remember desire, decision, and determination! Thanks again!*
5. Technology Integration

The Three D’s model played an essential role in helping students become more motivated to learn. The role of technology integration was also a central feature of the success. The online testing that occurred allowed students—especially those with learning difficulties—to retake the Accelerated Reading quizzes until they could master the intended outcome. Without the online Treasures Reading weekly assessments, students would likely not have moved from the “below” or “basic” levels at the beginning of the year to the “advanced” level at the end of the year. This is a significant change in performance. Improvement of this magnitude demands real effort from both learner and teacher. But without the option of online testing, the teacher would be hard pressed to provide students needed feedback to succeed. Both teacher and students became determined enough to succeed. And when they experienced success, their desire for more success increased.

In addition to the Treasures Reading weekly assessments, students also completed the STAR Reading Test on a monthly basis that measured their reading level, as well as weekly Accelerated Reading quizzes that measured their comprehension skills in the Treasures Reading. These online assessments provided students with feedback on what they needed to learn to attain mastery. Students exercised their agency to retake online Accelerated Reading quizzes. Not only did the assessments provide instant feedback for students, but the scores provided information for the teacher so that instruction could be aimed at the specific needs of students. The data were also used to reinforce student progress. In other words, when the entire class did well on an assessment, the teacher could confirm their success so that they could recognize their own improvement and then be more motivated to move to the next level of performance.

Success in one subject also helped motivate students to improve in other subjects. For example, one student who had struggled in math, achieved advanced proficiency in reading and pushed herself to do the same in math. At the end of the year, while students were in the computer lab working on their final projects, this student had completed every assignment and asked: “What can I do now?” The teacher responded, “I guess you could play games.” Rather than playing games, she asked if she might take one more math test online to see if she could get above 90%. She accomplished her goal and was excited to achieve success in mathematics, as well as in reading. She used her personal agency and chose to learn rather than using her extra time in some other way.

6. Conclusion

The Three D’s of Success model can be an effective tool for teachers who are trying to help their students master learning outcomes while increasing their power to exercise their own agency. To help students become more “determined” learners, they need feedback on their performance. Online testing can be an effective tool to provide such feedback. Although online testing is not a particularly new use of technology, the application of the technology in this case study is unique. By using the Three D’s Model in conjunction with online testing, students can actually look forward to taking exams because they come to see the exams as a means of demonstrating their progress on the pathway to success. Then, as they experience more success, their desire to attempt more difficult learning tasks increases. Rather than escaping the challenging
learning task, they are more likely to seek for it. They welcome the occasion to demonstrate their mastery of a learning outcome rather than shrinking from it. In these ways their power to exercise their personal agency increases and they experience ever greater amounts of success.

References

Applying creativity to Teaching in Computer Science: An exploratory learning course with LEGO Mindstorms robots

Mikko APIOLA\textsuperscript{a}, Jaakko KURHILA\textsuperscript{a}, Matti LATTU\textsuperscript{b} and Tomi A. PASANEN\textsuperscript{a}

\textsuperscript{a} University of Helsinki, Department of Computer Science
\textsuperscript{b} University of Helsinki, IT Department

Abstract. The purpose of this paper is to explain a teaching experiment at the University of Helsinki Department of Computer Science (CS). The experiment consists of an intermediate-level CS course using LEGO Mindstorms robots focusing on creative working methods. The purpose is to try an arrangement where the course structure is very open both for the instructors and the students. Our course sessions concentrate on creative working methods. The presumption is that openness will support intrinsic motivation, which combined with creative working methods will lead to creative coursework. The plan is to gain knowledge on motivation, creativity and the use of Mindstorms robots in teaching CS.

Keywords. creativity, motivation, LEGO Mindstorms

Introduction

LEGO Mindstorms is a robotics kit based on a small microcontroller unit, a set of input sensors, motors and parts for building robots. The robot can be programmed natively with NXT-G visual programming software which comes bundled in the microcontroller. However, there are a range of third-party programming languages to allow significantly more sophisticated programming. NXT-G is adequate for very basic programming and learning simplified programming structures and flow control whereas e.g. libraries for Java [1] and C/C++ [2] enable to utilize the full potential of more advanced programming languages.

We at the University of Helsinki CS Department became interested in Mindstorms mainly because we wanted to add creativity and meaningful fun into our study environment. Mindstorms was also seen as a possible tool for making programming more concrete for freshmen while it could also offer a framework for more advanced domains, e.g. artificial intelligence (see e.g. [3][4][5][6][7][8][9]). After some preliminary planning and research [10][11] the department decided to purchase 60 Mindstorms sets.

This paper describes the first, ongoing teaching experiment at the University of Helsinki CS Department where the Mindstorms kits are put into practice. The course does not have any clearly defined learning objectives. Instead, we have a set of goals that were presented for the students in the course description and at the first meeting: students must put together a robot that passes a defined task; solutions used must be technically well-documented; and we deliberately stated to the students that we want...
them to explore, have fun and even amaze us and the other participants. We also told
them that the problems would be used next semester in the basic programming courses
targeted for the 1st year students. Thus, the students were also required to document the
learning objectives that their project would rehearse with future students.

The course is optional for the students and they were recruited through the
department mailing list. Since Mindstorms is a new tool for us we did not want to bring
it straight to our standard curriculum. An optional course with interested students was
expected to help us in setting standards for the compulsory courses and finding the
possible technical problems with Mindstorms and our environment.

One of the main reasons to explore Mindstorms in CS teaching was to enhance
students' skills in creativity. Creativity is something which involves producing original,
unexpected and useful work (for example [12]). As Herrmann [13] summarizes a
variety of definitions, creativity is about “the ability to challenge assumptions,
recognize patterns, see in new ways, make connections, take risks, and seize upon
change”. Creativity is widely thought of as something which is important in a wide
range of task domains, for example in different kinds of problem solving tasks
(example [12][14][15]). Work of creativity pioneers, such as Torrance [16] and
Amabile [17] has concluded that in organizations and schools individual creativity is
killed much more often than it is supported, yet they are convinced that it is possible to
design education and working conditions which support both rationality and creativity.
Maturation and socialization processes can build many kinds of locks or mental blocks
for creativity; for example, psychological barriers and cultural locks can occur in a case
where playfulness, fantasy and reflection are trained out of people by stressing e.g.
efficiency and effectiveness [15]. The contradicting requirements of performance and
creativity have recently put a lot of pressure on educational institutions in many
industrialized countries (see e.g. [14]).

Crucial attention has been drawn to intrinsic motivation in creative endeavour (for
example [17][18][16][12]. An intrinsically motivated person engages in an activity
primarily for her own sake; because the activity is perceived as interesting, involving,
satisfying or challenging while in contrast, an extrinsically motivated person acts
primarily in order to meet some goal external to the work itself, such as attaining an
expected reward or external recognition. Of course the issue is not straightforward, and
extrinsic motivation can also be divided into creativity-detrimental controlling extrinsic
motivation, and creativity-enhancing informal or enabling extrinsic motivation [19].
For example, extrinsic motivators which support one's sense of competence or increase
involvement in the task may act together with intrinsic motivators to increase creativity.
Extrinsic motivators can also serve to bring people in contact with a topic that can
engage their interest. In practice, the best way to maximize intrinsic motivation is to
allow people to do something they love (for example [20][18]). This means for
example, allowing students to choose their own topics and controlling extrinsic
constraints; evaluation, surveillance, task constraints, competition and giving
informational, constructive, non-threatening and work-focused feedback [20][21][18].

1. Intrinsic Motivation and Creative Processes

Creativity has remained an ill-defined concept despite the vast discussion around it.
Starting from the 1950s the amount of research involving creativity has seen a huge
expansion and seems to span through almost any domain of science from medical to art,
technical to business, not to mention psychology and other behavioural, social and educational sciences. Despite the difficulties in definitions, creativity and creative skills have become something which is regarded highly important within practically every field of work. Pioneers in creativity research have come to share quite similar views: that creativity is something which requires three components: domain relevant skills (expertise and talent in task domain), creative processes (cognitive skills and work styles) and intrinsic motivation (for example [22][12][18]). It is also widely accepted that creativity is something everyone is capable of, it is not a special talent of a gifted few, and that creativity can be enhanced or blocked in many ways.

Creativity-enhancing processes are based on the thought that creativity requires an environment which encourages risk taking and self-initiated projects and provides help and time for developing ideas and individual effort. A recent meta-analysis [23] summarizing 62 previous research papers reports positive results for a positive-mood-enhances creativity hypothesis. Incubation is often mentioned as an important factor in creativity processes. Incubation means flashes of insight into a problematic task that come while doing something else, but work on the task itself. A recent meta-analysis consisting of 117 previous research papers on incubation [24] concludes that although straightforward conclusions are hard to make due to the varying methods used in the analysed reports, the results support the existence of incubation effects and that problem-solving tasks were likely to benefit from an incubation period. So it seems, that in creative problem solving, a positive mood and enough incubation time are enhancing factors.

There are several methods for enhancing creativity, of which methods especially intended for concrete problem solving situations include, for example, brainstorming [25], verbal check-lists [25][26], picture stimulation [15] and mind mapping (for example [27]). Higgins [28] has also provided many methods for enhancing creative problem solving. A general idea with many of these methods is the purpose of generating ideas by suppressing the common tendency to criticise or reject ideas. For example, in brainstorming sessions all criticism is forbidden and the generation of a large number of ideas and their combinations are encouraged. The goal behind the verbal check-lists is to delete old ways of thinking and go for different directions using a list of verbs which are associated with an idea or product under work [15]. A main idea behind all these methods is to create a psychologically safe atmosphere which encourages new kinds of associations for ideas and solutions using different types of games or tasks. These methods have been and can be used in many kinds of teaching involving problem solving.

Although intrinsic motivation appears to enhance creativity it is also a favourable condition in itself. In their meta-analysis Ryan and Deci [29] link several attributes (interest, excitement, enhanced performance, and persistence) which are perceived for university students. The intrinsic motivation can be supported by a) social interaction that enhances feelings of competence, b) optimal challenges, effectance-promoting feedback, and freedom from demeaning evaluations, c) supporting internal perceived locus of causality, and d) providing choice, acknowledgement of feelings and opportunities for self-direction [29].

To summarise, the literature suggests that intrinsic motivation and creativity are linked. While the direction of causality is unclear the relevant studies argue that enhancing one supports also the other.
2. Our Course Design

The design of our course is based on theories about intrinsic motivation, creativity and creative working methods. We had a vision of highly motivated students, having fun, being creative, playing around with robots, and producing original ideas and coursework to be used later in teaching various CS topics using Mindstorms robots. The course is an optional course, since we wanted to gain more knowledge on how robots best could be used in teaching CS and also to find out what practical problems could occur. Optionality can also be seen as an intrinsically motivating factor. Intrinsic motivation is also attempted to be supported by minimizing the feel of superimposed control structures in the course; the amount of credit points to be earned is open, as well as the task and technology of the coursework. At some experiments it is considered a problem that students must come to specific sessions where they can build their robots [30]. In our course all attendants can borrow their own Mindstorms robot, so experimenting is not restricted to university grounds. Since there was no clear view on how and what should be taught using the robots, we came up with an idea to try creativity-enhancing problem-solving methods within our course meetings. Since the arrangement is open, it seemed important to require some background on technological skills (in other words, a grade from a course on data structures, widely regarded as one of the hardest intermediate-level courses at our department). In addition, this kind of course setting should take all requirements for creativity (intrinsic motivation, creative processes and domain-relevant skills) into account.

The recruitment for the course started from a message on the student mailing list and an announcement on the web pages of our department. Despite the short notice, the course turned out to be relatively popular with an enrolment rate of 42 students. Of these 42 students, 36 showed up to pick their Mindstorms robot. It has to be noted that the announcement for this kind of course came very late, just a couple of weeks before the course started. It should also be noted that, at our department, students can enroll in courses and never show up or they can decide to quit at any time with no sanction or entry in their study transcripts. Yet considering the late announcement and high robot pickup rate, this course can be considered highly popular. The students are from 2nd year students to postgraduate students. All students have good skills in computing. Our course is a 10-week course, which started at the beginning of March 2009 and lasts until the end of May 2009. The course includes six meetings. At the first meeting, instructions about documenting the project, information about the Mindstorms kit and some example robots were presented. Four meetings concentrate on supporting idea generation and promoting the process of building the robot by using creative working methods such as brainstorming.

At the first “creativity-meeting” all students were divided into three groups according to their preliminary interest domain, the groups were “navigation”, “pattern recognition” and “no idea”. The groups were then set in circles where in turns everyone were to present some idea regarding building the robot. Then the next student in the circle had to come up with three positive things about the idea and after that give critique in a positive form. The idea was to create a creativity enhancing, psychologically safe environment for ideas. At the second meeting students were parted into the same three groups. The idea was that each group would prepare all their ideas, possible solutions and problems in a poster. After preparing the posters half of the group would stay to present the groups poster, and half of the group could explore
the posters of other groups. At this session the idea of positive feedback was also encouraged.

At our third meeting course attendants were to present their current coursework. All students were set in a circle where in turns each pair were to freely present parts of their robot, program code, prototypes and ideas. The atmosphere of the meeting was positive with a lot of ideas, conversation and joy. This arrangement demanded little from the instructors, who did not do much but make sure there was enough space for everyone’s ideas. Examples of students’ preliminary coursework subjects included for example pattern recognition or navigation tasks. Examples of subjects were a gun robot which moves and shoots rubber bands where it observes movement, a coin recognizer, a checkers-playing robot, a chess-playing robot, a robot which simulates a sorting algorithm using different coloured balls. A couple of robots were planned to navigate in an environment trying to find some defined subject and trying to track their route in some way using, for example reinforcement-learning algorithms. The fourth meetings will follow a similar idea as the third meeting; it will also concentrate on presenting parts or prototypes of already working solutions. The final meeting is for presenting the final coursework.

To complete the course the following phases are required: designing, building the robot, programming and testing. All of the phases must be documented according to the documenting standards at our department. Important aspects of the project are negotiation with others, and the presentation of ideas and solutions. The students are encouraged to work in pairs. The evaluation will be done by a peer-evaluation, in which the students will evaluate each others' work, yet the final decision is left for the instructors. The study credits earned will be decided by the instructors.

3. Roadmap

The interest towards experimenting with new teaching methods can be tracked to fundamental questions concerning CS curricula. The teaching and research at our department is often considered of high quality, for example the Finnish Ministry of Education elected our department as one of the national centres of excellence in higher education from years 2007-2009 and 2010-2012. There is no doubt that most of our lecturers are highly trained and experienced, yet the majority of the teaching a student confronts is conducted by course assistants, often students themselves with limited pedagogical training and teaching experience. Several teaching theories stress the importance of, for example, appropriate feedback and reflection, teamwork and support, it could be asked what the reality which a student confronts is, and how the quality of teaching is to be defined.

As to the question of what should be stressed in CS teaching, many computer scientists would likely argue in favour of top-notch CS research when compared to, for example, projects such as ours. Still, the majority of CS majors will not end up as scientists, but, for example, working in the industry as experts. You could ask, how do the skills and abilities one develops while studying CS correlate with the reality faced in the industry and how direct should the correlation be? Or how much do they correlate with the skills needed as a researcher? Which kind of students drop out, end up as scientists, in the industry, or some other place? What are the outspoken or hidden objectives of our degree programmes? Whom do we want to educate? At the moment,
the input and output of the learning trajectory [31] and the pedagogical aspects of our degrees are relatively loosely defined.

Drawing from the previous positive experiences on teaching CS using LEGO Mindstorms, theories on creativity and intrinsic motivation, our pilot course is a step towards researching and refining our CS curricula. As an outcome of the course we gain insight into a) motivation factors at this course b) the kind of creativity that occurs c) practical questions concerning teaching with LEGO mindstorms and d) ideas for the use of robots in other CS courses. In order to gain insight into motivation and creativity we are interviewing all course attendants at the beginning and at the end of the course. The analysis of the interviews is done using doubled peer-analysis by two educational technology researchers. The analysis is based on grounded theory [32][33].

At the first interview we are looking for motivating factors towards studying computer science and motivating factors towards our course. At the second interview we are looking to gain knowledge on the process of building the robot and completing the course, focusing on creativity. Possible research interests for the future are to investigate the opinions of our CS department staff towards teaching with LEGO mindstorms, how the approaches of this course can be extended to ordinary courses, what requirements this kind of course setting will demand from instructors compared to ordinary courses, what kind of students will be motivated by this kind of courses, what creativity means in the context of CS, what courses and topics and how and why, could be taught using LEGO mindstorms.

One interesting phenomenon is that the course attendants set up an IRC (Internet Relay Chat) channel during the course where matters related to conducting the coursework were frequently discussed. With the permission of the course students, we are planning on analyzing the log of the above-mentioned IRC channel to explore what kind of interaction took place. In the future an interesting aspect would be to experiment with more social software for between-meetings interaction.

Our plan is to experiment using Mindstorms robots in a) autumn 2009 in our mandatory first year course Programming Project, b) in spring 2010 in our first programming courses Introduction to Programming and Advanced Course in Programming, c) in autumn 2010 in an intermediate mandatory course Introduction to Artificial intelligence and d) in spring 2011 in the advanced course Basics in Robotics.

References

Digital Natives' Learning and Teaching: the Amazonia Serious Game Scenario

Ines DI LORETO1,2, Abdelkader GOUAICH1, Fabien HERVOUET2, Guillaume DALICHOUX2, Alexandre FOUCHER2, Panupat PATRAMOL2, Stefano Alessandro CERRI1.

1 LIRMM: Laboratory of Informatics, Robotics, and Microelectronics of Montpellier

Abstract. Prensky’s talk about Digital Natives and Digital Immigrants is often used as a milestone for the field of study addressing this “new generation” of users. However, when talking about Digital Natives the general attitude is to think of them simply as students and not as perspective teachers. This is, in our opinion, a lost opportunity: their way of studying and doing things at present will influence the way they will work in their future workplaces. When they will assume, for example, the role of teachers, what kind of tools and environments will they really need? We will try to address this problem analyzing a project we held with four master’s students, for the creation of a serious game about Amazon deforestation, were they had an interesting role, at the crossroad between students and teachers.

Keywords. Co-adaptation, Digital Natives, serious games, user modeling, learning environments

Introduction

The intersection of Technologies and Education in general, and AI&ED in particular, have historically been marked by several profound debates - and by the corresponding research orientations- disputes, arguments, often rich of paradoxes.

In our opinion, these debates are still useful as reference points for the past but rather limited for the future, since the oppositions concern a teaching versus a learning centered approach, or a formal versus informal learning [1]. For the rest of the paper, our position will be as much as possible the one of observers of the "natural" phenomena occurring in learning (and in learners, Digital Natives[2]) having the goal to identify what kind of conception will be likely to be used by the same people once they will become teachers (in the deep sense of the term: at school as “real” teachers, as seniors in the workplace, as parents with their children) in the information society of the next years. Our conviction is that the real revolution within society, schooling included, will emerge not from new laws, curricula, instructional design methods, tools or professional training investments, but from the radically different approach in

1 Corresponding author. Laboratory of Informatics, Robotics, and Microelectronics of Montpellier (LIRMM) University Montpellier 2 & National Center of Scientific Research (CNRS) 161 Rue Ada, 34392 Montpellier, France E-mail:diloreto@lirmm.fr On leave from DICO – Dept. of Informatics and Communication, Università degli Studi di Milano, Via Comelico, 39, Italy

2 Students attending the master on informatics at the University Montpellier
solving problems adopted "naturally" by Digital Natives, that will impact their teaching methods, at home as well as at school. In this position, we totally adhere to the authoritative views express by Eileen Scanlon and Tim O'Shea [3] and by Marc Eisenstadt [4].

Nowadays, Digital Natives are migrating into a workplace run and organized by the “previous generation” natives. Obviously, the first scenario we can think about is a workplace world dominated by Digital Immigrants (elders who often feel less at ease with new technologies), a place where Digital Natives adapt to Digital Immigrants technologies and working methods. However, at a certain moment Digital Natives will be the only generation present in this imaginary workplace. If we focus on the educational field, this means that Digital Natives will be the only “teachers” for the “next generation” of students. For this reason, it will be interesting, to answer to questions such as: How different are they from previous students and will be from previous teachers? Will they need tools or environments different from previous ones?

While an articulated answer to these questions would need an ethnographic approach, we will try to sketch out some implications based on the evolution of a project that involved four Digital Natives with an interesting role, at the crossroad between student and teacher, as a preliminary source of reflections eventually to be further investigated.

In the rest of the paper, first of all we will talk about the subject of the project, a serious game for sensitizing players to the Amazon situation, that was, in our opinion, the first cause of motivation for the students’ involvement as “teachers”. In fact, the social impact of the project was a strong motivation for them, so that they took very seriously their educational role, as enablers for sensitization to Amazon problems. Next we will try to understand what kind of generation are our future teachers, the so-called Digital Natives. We will then get into the core of the project, basing on students' description of the tools they used for the project management, and we will finally sketch some implication.

1. The Amazon Situation

As we have said, the topic of the project was one of the motivations that caused the students’ switch from the “project developers” role to the “enablers” one. While the Amazon’s deforestation problem is a complex one, is worth to spend some lines describing it for better understanding why this switch happened.

In recent years, the Amazon has experienced high levels of deforestation, including the largest loss of forest on record between 2002 and 2004. Between May 2000 and August 2006, Brazil lost nearly 150,000 square kilometers of forest—an area larger than Greece—and since 1970, over 600,000 square kilometers (232,000 square miles) of Amazon rainforest has been destroyed [5].

Several studies tried to analyze the Amazon deforestation through models of deforestation patterns [6]. Results show that heterogeneous occupation patterns of the Amazon can only be explained when combining several factors related to the organization of the productive systems, such as favorable environmental conditions and access to local and national markets, proximity to urban centers and roads, agrarian structure, and so on. While for years, studying Amazon deforestation meant only study such deforestation patterns over the land, in recent years there was an important shift in the focus. Studies such as [7] state that containing the advance of deforestation in
Brazilian Amazonia requires understanding people actions, i.e. roles and movements of the involved actors. For example, landless migrants have significant roles in clearing the land they occupy, colonists and other small farmers are also responsible for substantial amounts of clearing, but ranchers constitute the largest component of the region’s clearing. Capitalized farmers, including agribusiness for soy production, have tremendous impact in certain areas, such as Mato Grosso. Landgrabbers, or grileiros, are important in entering public land and beginning the process of deforestation and transfer of land to subsequent groups of actors, and so on.

As we have seen, land changes in Amazon are the result of a complex web of interactions between human and biophysical factors, which act over a wide range of temporal and spatial scales. An important opportunity for us (the authors) to address such a complex scenario came when, in November 2008, two conditions were met:

- a conference was held in Manaus[8] where the key actors committed to the management of scientific knowledge by means of ICT met(among them one of the authors of this paper as invited speaker); and
- 4 master's students adopted a proposal for a "student's project": a "serious games" for knowing and learning the Amazonia biodiversity. We proposed them to exploit the simulations resulted from the GEOMA sub-projects [9] - in particular Dr. Tiago Garcia de Senna Carneiro projects 3 - in order to collaboratively design and prototypically implement a serious games about human decisions (such as deforestation) in Amazonia. We also proposed them a set of tools for asynchronous (such as Wikipedia) and synchronous communication (Agora, GSD and De Visu)[10][28].


Before addressing the way the project was managed by the students, it is in our opinion interesting to understand the way our students' generation address learning and technologies.

From a vital statistic point of view, the so-called Digital Natives generation includes people born between 1981 and 2000. However, we can see them under a technological perspective. Today's 24-year-old was born in 1985 – “10 years after the first consumer computers went on sale and the same year that the breakthrough "third generation" video game, Nintendo's "Super Mario Brothers," first went to market. When this 24-year-old was a child, the basic format of instant messaging was developed. And at the time he entered kindergarten in 1990, Tim Berners-Lee “wrote a computer program” called the World Wide Web. At the dawn of high school (for him in 1999), Sean Fanning created the Napster file-sharing service. When he graduated from high school four years later, his gifts might have included an iPod (patented in 2002) and a camera phone (first shipped in early 2003). Our 24-year-old college career saw the rise of blogs (already two-years-old in 2000), RSS feeds (coded in 2000), Wikipedia (2001), social network sites (Friendster was launched in 2002), tagging Del.icio.us was created in 2003), free online phone calling (Skype software was made available in 2003), podcasts (term coined in 2004), and the video explosion that has

3 Computer Science Department Federal University of Ouro Preto (UFOP)- Brazil; Head of TerraLAB - Laboratory for Modeling and Simulation of Earth Systems, National Institute of Space Research (INPE)
occurred as broadband internet connections become the norm in households (YouTube went live in 2005).” [11]

As we can see from this little history, Digital Natives cannot be defined only through vital statistics, but through a set of characteristics and common experiences. As Palfrey and Gasser [12] claim, Digital Natives “are connected to one another by a common culture. Major aspects of their lives- social interaction, friendships, civic activities – are mediated by digital technologies. And they’ve never known any other way of life”. We can then say that Digital Natives are characterized by a set of common practices, including the amount of time they spend using digital technologies, rather than by their age.

From a “learning” point of view: “Digital Natives are used to receive information really fast. They like to parallel process and multi-task. They prefer their graphics before their text rather than the opposite. They prefer random access (like hypertext). They function best when networked. They thrive on instant gratification and frequent rewards.” [2]. Moreover, they like to “learn by doing” (doing is more important than knowing, and learning is accomplished through trial and error) and they consider human interaction an essential part in the learning process [13]. Furthermore, Studies at the Pew Internet & American Life Project [14] show that virtually all college students play video, computer or Internet games, and 73% of teens do so. As a result, for example, they become accustomed with a style of learning that takes place informally [15].

Finally, if we look at their views on technology:

The definition of technology is not confined to computers or the Internet. Technology is viewed as any electronically based application or piece of equipment that meets a need for access to information or communication. For Digital Natives, technologies that are still considered transformative by their parents’ and grandparents’ standards (for example, instant messaging) are a basic part of their everyday lives. For them, technology is simply “what’s new”.

Customization is central to their definition of technology. Technology is something that adapts to their needs, not something that requires them to change. For them customization is the ability to adapt technology to meet individual needs, rather than vice versa [16]. The use of available technologies is precisely what we found very interesting in the way our students approached a project that, paradoxically, is clearly centered on the production of new technologies. In the next paragraphs, we will address this aspect in order to find what will be the “future generation” of teachers’ approach to technologies.

3. The Amazonia Serious Game Project: the Story so Far

As we have said, the complexity of the Amazon situation is based on land changes and at the same time on people behavior. In order to address such a complexity we (as teachers) decided for the creation of a serious game. In the purposes of the project, such a mean will allow us to achieve two major goals: sensitize people (perspective users of the game) to Amazon problems, and model users’ behaviors and believes through their own taken actions (the first may be considered a pedagogical goal, the second one a kind of experiment for group modeling). In the first part of this section, we will detail our motivation for the choice of the serious game as “pedagogical” mean, in a general way. A description of the generated serious game would be an interesting element of
analysis for understanding better why the students take very seriously their educational role, i.e. their role as enablers for sensitization (in fact, students also developed the history and worked on the game design). However, for our purposes – understanding Digital Natives’ approach to technologies in order to identify what they will need when they will become teachers – it is more interesting to analyze the way they approached the other technologies they used. In the second part of this section, we will show what “really happened” when students started to work for the project.

3.1. Serious Games and Learning (or, old generation, very academic reasons for the approach)

The serious games movement started with the U.S. Army’s release of the video game America’s Army in 2002 [17][18]. The same year the Woodrow Wilson Center for International Scholar in Washington, D.C. founded the Serious Games Initiative, and the term “serious games” became widespread [19]. The term itself is nowadays established, but there is no current single definition of the concept. Serious games usually refer to games used for training, advertising, simulation, or education, which are designed to run on personal computers or video game consoles.

Among the various (more or less) formal definitions for serious games, we like Zyda’s [20, p.26] words:

“Serious game: a mental contest, played with a computer in accordance with specific rules, that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives."

When comparing serious games with just computer games, Zyda argues that serious games have more than just story, art, and software. It is the addition of pedagogy activities that makes games serious. Now, we want to take his pedagogy term in the Greek original sense: paidagōgoi; from παιd: child and ἀγω: lead; literally, "to lead the child". So, in our vision, serious games are not simply a way to "instruct” about something (a skill or a competence) but a way to convey knowledge within a motivationally rich context (enabling the self construction of knowledge but not excluding the acquisition of scientifically correct information), and, why not, sensitize people about potential consequences of behavioral choices performed while playing.

If we can think serious games in this way, the question of interest concerns the claimed positive effects of such games, or of their applications from related and sometimes overlapping areas such as e-learning, edutainment, game-based learning, and digital game-based learning.

Corti [21], considers that Game-based learning (GBL) and serious games have the potential of improving training activities and initiatives by virtue of, e.g., their engagement, motivation, role playing, and repeatability: failed strategies etc. can be modified and tried again. Digital game-based learning (DGBL) is closely related to GBL, with the additional restriction that it concerns digital games. Analyses have been conducted over the years, consistently showing that games promote learning [22][23].

DGBL is, following Prensky [24] ideas, based on two key premises: firstly, the thinking patterns of learners today have changed, that is, today’s students are ‘native speakers’ in the language of digital media. Secondly, this generation has experienced a radically new form of computer and video game play, and “this new form of entertainment has shaped their preferences and abilities and offers an enormous potential for their learning, both as children and as adults” (ibid., p. 6).
So, we posed ourselves the same question as Squire et al.[25]: how educational technologists will respond to the “digital native speakers”, i.e., “a generation of students who, raised on interactive games, expect the same kinds of interactive experiences from their educational media?” (p.34).

As we have mentioned, our answer was linked to our idea of pedagogy: we will convey knowledge through a serious game, and the game will not be an educational game in the classical sense of edutainment: it will talk the Digital Natives’ language.

3.2. Bring the project to light (or, what really happened when Digital Natives become enablers/ pedagogues)

Towards the end of the project, we asked our students to describe what kind of tools they used for managing their work (as we have said in par.1 some were proposed by the teachers, but, as a matter of fact, most of them were chosen by the students). They produced a report describing the tools but also why they found them useful (or not). In the rest of this section, we present a synthesis of their report that will be analyzed in the last section in order to identify a few properties of our experiment supporting or refusing convictions about the needs for tools in the years to come.

**Flash Meeting:** The first software they were asked to interact with was Flash meeting (FM)[26], an Open University’s[27] project that implements a set of collaborative tools to manage real time video meetings with participants from all over the world. From a technological point of view, students found very interesting the simple way used to access the meeting (a web browser with Adobe Flash and an internet connection). They also liked the easy way to manage “speaking turns” through queues, a functionality that is not available in most Instant Messaging software.

From an organizational point of view, they found compelling that the meeting has a limited duration (nearly one hour and a half in each case), because this forced them to effectively prepare it, thing that they never did for their “informal meetings”. Finally, they considered the possibility to record the meeting the most important feature of this tool “because when you make a meeting speaking English with participants from different nationalities, it is very important to listen a few times more the conference, to make sure you well understood everything”. Their final comment on FM was that “It is full of interesting features to help the collaboration and to forget that the meeting is virtual”.

**Face to face meetings:** The students also participated in (more or less formal) face to face meetings. The “formal” meetings were held in the LIRMM laboratory - with the teacher presence while the “informal” ones were held at one student’s home. They considered the first kind of meeting as an opportunity to summarize and discuss the ideas they had since the last meeting (for example they reviewed the needs and the roadmap of the project). In their words, “It allows to give everyone a global vision of the project and especially to motivate the troops”.

Meetings at home were their informal way to manage the project. It’s interesting to note that nobody told them to do this kind of meeting (nor to add others tools). Simply, where they felt a gap in communication or in project management, they instinctively filled it. They liked this kind of meetings because “there are more ideas that spring out, and you are allowed to think in a more easy way”. Moreover, the process of stay together and eat together after the meeting contributed to improve, as they said, the cohesion of the work group, because it allowed them to know each other better.
Skype: In students’ analysis, Skype’s main drawback, compared to tools like Flash Meeting, is linked to the installation and registration process. If you want to communicate with someone, he/she has to download and install the software, and finally register a Skype account just to be able to receive your call or message (as we have seen FM uses a light web client and only the booker needs to register). They also found that the impossibility to record the meeting was a problem for their “professional” use of the tool. However, they found also important that everyone in Skype was able speak at the same time: “you can interact more easily and quickly with your interlocutor, and this is a way to be more efficient”. Their main interest in Skype was that they were able to use it in an instant way: if they were connected and they wanted to know what the others think about an idea, they just had to launch the Skype call (it’s very interesting to note that this implies that they were practically always connected to the application).

Agora GSD: Agora[28] is a platform which aims to deploy collaborative services among virtual communities on the internet. The Agora platform includes two collaborative services: The Grid Shared Desktop (GSD), a service for sharing any application, and De Visu, a video-conference service. For the project, the students experienced only the Shared Desktop.

Students had different opinions over this tool. From one hand they found it interesting because it allowed them to communicate and to collaborate thorough the shared desktop. In an occasion, when there was the need to show in a shared way the result of their work and they weren’t able to use Agora, one of them claimed that he would have really appreciated to be able to use it, exactly for the shared desktop idea. However, some of them found that “in face of this tool, not everybody is equal. The simple fact that we needed an introduction was not a good thing. What will happen to non-informatics people?” (they are referring to a demo that was held to show them the shared desktop functioning). We are sure that, if the project really needed a way to show in a guided, shared way the results, they will have found a tool adequate to manage it.

Wiki (based on MediaWiki, provided with Agora): In students’ opinion, for the project the wiki [30] was not used as a communication tool, but as a tool for future collaboration. In their words, “Maybe this project will go on after we will be forced to stop it, with other students next years. If so, the wiki is a huge amount of knowledge, a trace of what we thought, discussed and decided about it.” They really liked the idea to let a persistent trace of their work, and the direct evidence of this statement is that they spent a significant amount of time not only “filling” the wiki’s pages, but also “personalizing” it, through images and little “hackings” in order to adapt the wiki to their needs (this match with Roberts’ founding about Digital Natives approach to customization, see par.2). Summarizing, for them the wiki provided a well-structured and centralized outcome, an organized persistent trace of their knowledge and their decision processes.

Emails: When they analyzed this communication tool, they found the already well-known advantages and disadvantages of asynchronous communication. You don’t need to set an appointment to send a mail, and you can send information in a message whenever you want. Messages are almost sent to everyone in the group, so there is a persistence of these messages. However, the way we used mails (through simple clients and not based on a repository) generated some versioning problem with the attached files. This is why they searched, found, and used alternative tools for managing the problem.
SVN (GoogleCode): Google Code Subversion (SVN) [29] is a mean to manage concurrent versions of files on large projects. Students decided to use it because it allowed them to work at the same time without fearing data loss (you can easily restore any old version of a file uploaded before). An interesting remark over this tool was “we are getting used to it, because it is a very common tool in development, and widely used”.

DropBox: DropBox[31] is a software that allows you to create a shared directory which could be easily synchronized between collaborators, just using an Internet connection. The students adopted it spontaneously (as they did for Skype, SVN, and the informal face-to-face meetings), because they liked it’s “collaboration oriented” space. In fact, everyone can access the files they put in the shared directory at anytime. However they found a lack in the potentiality of the tool. In fact, every time they added a file they had to send an e-mail to announce it. “It wasn’t a communication tool because each time we shared a new file with DropBox, we have to send a mail to everybody to inform them of its existence, but it really dealt with knowledge sharing because everyone of us may decide to create a new file and to put some knowledge into it...”

4. Lessons Learned

Based on the above-described student report, in the rest of the paper we will try to outline some interesting aspects that emerged when we tried to abstract from it:

The fading of real/virtual opposition: First, when we asked them to list all the tools they used for communication, they naturally added face-to-face meetings. While their comment on Flash Meeting let think otherwise (“It is full of interesting features to help the collaboration and to forget that the meeting is virtual”) it is our opinion that this is a concrete sign of the fading of the traditional real/virtual opposition (meeting with pizza and meeting with Skype are considered at the same level). In fact, both – face-to-face meetings and ‘virtual’ meetings- were recorded (i.e., a synthesis of each meeting was made disposable for the others to work with).

This in our opinion means that future “teachers” will easily use “virtual” and “real” means for their purposes, so they will need environments that will allow them to switch seamlessly between the two.

A love for persistence: It’s interesting to notice that the students searched tools able to offer persistence (e.g., the files repository and the wiki) to their work. Moreover, they liked the permanence of video meetings - where virtual meeting became real also through its permanence and repetition, and therefore through its availability throughout the whole history of the project. However, more than the wiki, the video-meetings were viewed several times, and were used within the game development (contrary to what happens in most projects).

This means in our opinion that future “teachers” will need environments able to support persistence of events (and the associated retrieval of stored events).

MashUps as a natural instinct: This is in our opinion the most interesting aspect. As we have noticed, if students found a gap between the tools they were required to use and their needs, they filled it instinctively (as most young people do in internet trough mash-up [4]). The lack of functionalities didn’t stop their work. On the contrary, the gap pushed them to find integrations able to support their work.
In our opinion, this implies that this generation of perspective “teachers” - that is already used to mash-ups - will not need pre-packed tools but, more and more, environments were the current and future tools would be accessed and made available for use.

The new Media Fluency for informal learning: Some of the tools our students listed addressed very particular computer scientist problems (e.g. SVN and DropBox addressed the problem of managing file versioning). However, if we try to abstract, we can note that for them creating a project was all about communication, knowledge creation and knowledge management/sharing. In their report, they never mentioned the tools for “creating” the game. This may seem at first a little bit strange, because nobody instructed them on how to build a game. However, they made instinctively interesting suggestion about how to create it, because, for them, games are experienced tools. We can note the same concerning Skype: most of the tools they used were not “learned” at school, but in an informal way. Moreover, their use of communication tools (e.g. Skype for a quick call about an idea) let really think about peer supported learning.

This in our opinion means that future “teachers”, will be literate on many different “new” media, unlike the old generations , and will give much more importance to collaboration, social and informal learning (learning from the others, learning from the context, learning by doing) than to the “tools” they are using (learning at school from books, following curricula ).

5. Conclusions

As we have already said, we didn’t use an ethnographic approach, so this paper has no pretenses to give any definitive response to the formulated questions. However, we think that in the development of the project some interesting elements emerged that will be worth of further in-depth examination.

Sensitization about Amazon deforestation was, for the students-enablers, the primary goal of this project. The social impact of the project was for them a strong motivation so that they took very seriously their educational role, as enablers for sensitization to Amazon problems. We think that the creation of a (serious) game -a well known medium for them - had the advantage to let them focus on management and development issue, rather than on the medium fluency (as it often happens with other kind of applications that are given to teachers for their use). We know that our students were a very particular kind of students (high level of abilities in informatics, high motivation, and so on) but it is our opinion that future teachers will be the same: considering tools (including perhaps classical concepts in curricula) as commodities and not as the scope of what they are doing, and, in the best of possible worlds, highly motivated. Moreover, we may assume that as teachers they will focus on abstracting and generalizing the instance of the solving problem process itself to new contexts, rather than in the art of constructing new tools and applications for solving new problems, because they will assume their students will need the same as what they needed themselves when they were students.

References

Zebra: A New User Modeling System for Triangular Model of Learners’ Characteristics

Loc NGUYEN
University of Science, Ho Chi Minh city, Vietnam

Abstract. The core of adaptive system is the user model that is the representation of information about an individual. User model is necessary for an adaptive system to provide the adaptation effect, i.e., to behave differently for different users. The system that collects user information to build up user model and reasons out new assumptions about user is called user modeling system (UMS). There are two main tendencies towards implementing UMS: domain-independent UMS and domain-dependent UMS. The latter is called generic UMS known widely but our approach focuses on the domain-dependent UMS applied into adaptive e-learning especially. The reason is that domain-independent UMS is too generic to “cover” all learners’ characteristics in e-learning, which may cause unpredictable bad consequences in adaptation process. Note that user is considered as learner in e-learning context. Many users’ characteristics can be modeled but each characteristic is in accordance with respective modeling method. It is impossible to model all learners’ characteristics because of such reason “there is no modeling method fit all characteristics”. To overcome these obstacles and difficulties, we propose the new model of learner “Triangular Learner Model (TLM)” composed by three main learners’ characteristics: knowledge, learning style and learning history, TLM with such three underlying characteristics will cover the whole of learner's information required by learning adaptation process. The UMS which builds up and manipulates TLM is also described in detail and named Zebra. We also propose the new architecture of an adaptive application and the interaction between such application and Zebra.

Keywords. User modeling system, adaptive learning

Introduction

User modeling system (UMS) is defined as the system that collects information about to build up user model and reason out new assumptions about user. UMS (s) have a long evolutionary process from early user modeling systems embedded into specific application to user modeling shells and user modeling servers which are separated from adaptive system and communicate with adaptive system according to client-server architecture. Note that the term “UMS” indicates both user modeling shell and user modeling server in this paper.

Before discussing main topic, we should glance over existing UMS in section 1. Section 2 described the Zebra – our modeling system in detailed. Section 3 is the conclusion.

1 PhD student at University of Natural Science, Vietnam.
1. Existing user modeling systems

1.1. Early user modeling systems

Early UMS (s) concentrate on question-answer (dialog) system and human-computer interaction. They are components embedded in concrete application. An example for such dialog system is GRUNDY [1] developed Rich in his PhD thesis. GRUNDY play the role of book recommender in the library when it calculates recommendation of books, based on assumptions about users’ personal traits. Such traits which are educational and intellectual level, preference for thrill, fast-moving plots or romance, tolerance for descriptions of sexuality, violence and suffering… are represented as user model. GRUNDY use stereotype method [1] to build up user model, based on users’ answers to questions during their first usage of system. For example, if user has a mail first name, GRUNDY infers a high sex tolerance and a low one for romance.

1.2. User modeling shells

There is a need for developing UMS (s) as separated components whose functionality is not dependent on any adaptive application. Such UMS (s) are called user modeling shell. The term “shell” is borrowed from the field of expert system; thereby, the purpose of shells is to separate user modeling functionality from adaptive application. User modeling shell goes towards generic purpose but it is not totally independent on application and often integrated into application when it is deployed. Examples of user modeling shell are GUMS, UMT, PROTUM, TAGUS, um.

**GUMS**

GUMS [2] is the abbreviation of “General User Modeling System” developed by Tim Finin in his PhD thesis. It is a first modeling shell that abstracts information about user by allowing defining the simple stereotype [1] hierarchies in form a tree of structure. Each stereotype is associated facts and rules describing system’s reasoning about it. Moreover GUMS interacts with specific application by storing facts that application provides and answering any queries of application concerning assumptions about user.

**UMT**: UMT (User Modeling Tool) developed by Brajnik and Tasso [3] models information about users as stereotypes which contain their assumptions in form of attribute-value pairs. UMT allows developers/specialists to define hierarchical user stereotypes, triggers, rules for user model inferences and contradiction conditions.

**PROTUM**: PROTUM (PROlog based Tool for User Modeling) [4] is written by the programming language PROLOG. It is more powerful than UMT although it uses stereotype method to model user like UMT did because its hierarchy of stereotypes is not limited to tree structure and assumptions about users are not based on attribute-value pairs like UMT.

**TAGUS**: TAGUS developed by Paiva and Self [5] also applies stereotype method into modeling user. Thus it allows defining the hierarchical stereotype but each assumption about user in stereotype is represented in first-order formulas with meta-operators expressing the type of assumption such as: belief, goal…
um: um developed by Kay [6] aims to provide the library of user modeling functionalities in which assumptions about users’ knowledge, goal, background… are represented in attribute-value pairs

1.3. User modeling servers

User modeling server has the same purpose with user modeling shell when both of them aim to separate user modeling functionality from adaptive system. However user modeling server is totally independent on application. It is not integrated into applications and interacts with applications through inter-process communication. It can reside on the different site from application’s site and serve more than one instance of application at the same time. The communication between user modeling server and adaptive application is based on client-server architecture in which modeling server is responsible for answering application’s requests. Examples of user modeling server are BGP-MS, Doppelgänger, CUMMULATE, Personis.

BGP-MS: BGP-MS developed by KoSa and Pohl [7] is the user modeling server taking interest in user’s knowledge, belief and goal. It receives user’s observations provided by adaptive application and processes internal operations of classification and calculation based on these observations. BGP-MS use stereotype method, natural language dialogs and questionnaires to build up user model. BGP-MS has four essential components:
- **Individual user model** contains assumptions about user.
- **Stereotype** component manages the hierarchy of stereotypes.
- **Automatic stereotype management** is responsible for the activation and deactivation of assigned stereotypes of an individual user model

These main components communicate together through the *functional interface*. Developer interacts with BGB-MS by the *graphic interface*.

Doppelgänger: Doppelgänger [9] developed by Orwant is the server that monitors users’ actions and discovers patterns from these actions. Basing on such patterns, Doppelgänger aims to deliver user a personalized daily newspaper; it provides news in which user can be interested. The architecture of Doppelgänger is split into two levels: sensor level and sever level
- **Sensor level.** There are sensors having responsibility for gathering information about user. Sensors can be either software or hardware.
- **Server level:** Make inferences on information provided by sensors.

CUMMULATE: CUMMULATE [10] is developed as generic student-modeling server in which information about user is represented on two levels: *event storage* and *inferred user model*. Student actions being monitored are sent to event storage by a standard http-based event-reporting protocol. Such actions are considered events. CUMMULATE adds a timestamp to each event and stores it permanently in event storage. The event storage allows several *inference agents* that process events in different ways and convert these events into the inferred user model, for example, some agents monitor user’s knowledge and others predict user’s interests. The architecture of CUMMULATE is open to a variety of *external inference agents* that receive requests from event storage and manipulate user model.
Personis: Personis [11] is the modeling server whose considerable feature is to allow user to control and scrutinize his/her model. Such user model is called scrutable user model. Personis is based on um toolkit but more complicated than um toolkit. The architecture of Personis is divided into four parts:
- The server itself is responsible for managing user model.
- A set of generic scrutiny tools allow users to see and control their own user models.
- A set of Adaptive Hypermedia Application (AHA) are denoted AHA1, AHA2,…, AHA_n.
- A set of views in which each view of user model available to each AHA is responsible for defining the components used by such AHA.

LDAP-UMS: LDAP-UMS [12] is the user modeling server based on Lightweight Directory Access Protocol (LDAP). It focuses on data handling and enhances user modeling functionality by enabling user model to achieve “pluggable” feature. UMS uses a directory structure of LDAP to manage user’s information spreading across a network. The architecture of LDAP-UMS inherits the LDAP directory server; so, UMS is composed of several pluggable user modeling components and can be accessed by external clients. The core of architecture is the Directory Component attached its three sub-components: Communication, Representation and Scheduler.

2. Zebra: A User Modeling System for Triangular Learner Model

Exist user modeling systems develop fast in recent years; they are trending towards servers that give support to adaptive applications with fully response to queries about user information available in user model. However we recognize that generic UMS (s) are too generic to describe all fine characteristics of user when she/he is learner in e-learning context. Especially in situation that our research focuses on domain of e-learning, such UMS (s) prove to be less effective in providing assumptions about user to adaptive learning applications. In learning environment, users who play role of learners must be modeled by special method. The content of learner model can be divided into two categories: domain specific information and domain independent information. Domain specific information is knowledge that learner achieved in certain subjects. Otherwise domain independent information includes personal traits not related to domain knowledge such as: interests, learning styles, demographic information... Each kind of information is in accordance with respective modeling method. For example, knowledge model is often created by overlay method, which called overlay model. So it is impossible to model all learners’ characteristics because of such reason “there is no modeling method fit all characteristics”.

To overcome these obstacles and difficulties, we propose the new learner model that contains three most important characteristics of user: knowledge (K), learning styles (LS) and learning history (LH). Such three characteristics form a triangle; so our model is called Triangular Learner Model (TLM). TLM with three underlying characteristics will cover the whole of user’s information required by learning adaptation process. The reasons for such assertion are:
- Knowledge, learning styles and learning history are prerequisite for modeling learner.
While learning history and knowledge change themselves frequently, learning styles are relatively stable. The combination of them ensures the integrity of information about learner.

User’s knowledge is domain specific information and learning styles are personal traits. The combination of them supports UMS to take full advantages of both domain specific information and domain independent information in user model.

We also introduce the architecture of UMS which builds up TLM; it is named Zebra. The name “Zebra” implicates that our UMS will run fast and be powerful like African zebra.

2.1. Triangular Learner Model

TLM is constituted of three basic features of user: knowledge, learning styles and learning history which are considered as three apexes of a triangle (see figure 1). Hence TLM has three sub-models: knowledge sub-model, learning style sub-model and learning history sub-model.

![Figure 1: Triangular Learner Model](image1)

![Figure 2: extended Triangular Learner Model](image2)

We propose the method that combines overlay method and Bayesian network [13] to build up knowledge. In overlay method, the domain is decomposed into a set of knowledge elements and the overlay model (namely, user model) is simply a set of masteries over those elements. The Bayesian network is the directed acyclic graph (DAG) in which the nodes are linked together by arcs; each arc expresses the dependence relationships between nodes. The strengths of dependences are quantified by Conditional Probability Table (CPT). The combination between overlay model and BN is done through following steps:

- The structure of overlay model is translated into Bayesian network, each user knowledge element becomes an node in Bayesian network
- Each prerequisite relationship between domain elements in overlay model becomes a conditional dependence assertion signified by CPT of each node in Bayesian network

So knowledge sub-model is called as Bayesian overlay sub-model.

Learning styles are defined as the composite of characteristic cognitive, affective and psychological factors that serve as relatively stable indicators of how a learner perceives, interacts with and responds to the learning environment. There are many models of learning styles in theory of psychology such as: Dunn and Dunn, Witkin, Riding, Myers-Briggs, Kolb, Honey-Mumford, Felder-Silverman… We choose Honey-
Mumford [14] and Felder-Silverman model [15] as principal models which are presented by Hidden Markov Model (HMM) [16]. According to Honey-Mumford and Felder-Silverman model, learning styles are classified into following dimensions:

- **Verbal/Visual.** Verbal students like learning materials in text form. Otherwise visual student prefer to images, pictures…

- **Active/Reflective.** Active students understand information only if they discussed it, applied it. Reflective students think thoroughly about things before doing any practice

- **Theorist/Pragmatist.** Theorists think things through in logical steps, assimilate different facts into coherent theory. Pragmatists have practical mind, prefer to try and test techniques relevant to problems

For modeling learning style using HMM we must define states, observations and the relationship between states and observations in context of learning style. So each learning style is now considered as a state. The essence of state transition in HMM is the change of user’s learning style, thus, it is necessary to recognize the learning styles which are most suitable to user. After monitoring users’ learning process, we collect observations about them and then discover their styles by using inference mechanism in HMM. So learning style sub-model is modeled as HMM.

The last sub-model stores and manipulates learner’s **learning history** in form of XML data files. All learners’ actions: learning materials access, duration of computer use, doing exercise, taking an examination, doing test, communicating with teachers or classmates… are logged in this sub-model. School reports also recorded in this sub-model. We consider this sub-model as a feature of learners because every student has individual learning process in her/his life and the data about such learning process are recorded as pieces of information in learning history sub-model. Information in this sub-model is necessary for data mining in e-learning to discover not only knowledge and learning styles but also other learners’ characteristics such as interests, background, goals… The mining engine in the core of Zebra often uses this sub-model for many mining tasks. For this reason, this sub-model is drawn as the apex at the bottom of triangle in architecture of TLM. This implicates that learning history sub-model is the most important sub-model in TLM when it is considered as the basic of two other sub-models. Figure 2 shows the extended TLM in which learning history sub-model is the root for attaching more learners’ characteristics such as interests, background, goals… to TLM.

### 2.2. The architecture of Zebra

The essence of user modeling systems is mining user’s profile to discover valuable patterns in form of user’s features. These features which are personal traits or characteristics in learning context navigate adaptive applications to give support to user in her/his learning path. The purpose of Zebra is to mine user’s learning profile to build up her/his TLM. Hence Zebra has the inside **mining engine**.
Moreover, Zebra must implement the powerful inference mechanism to reason learners' new assumptions (or characteristics) out TLM. In section 3.1, we propose two methods: Bayesian network combined overlay model and hidden Markov model to infer learners' knowledge and styles. Both Bayesian network and Markov model are special cases of belief network. In general, a belief network is directed acyclic graphs in which nodes represent variables, arcs signify direct dependencies between the linked variables, and the strengths of these dependencies are quantified by conditional probabilities. Belief network is the robust mathematical tools appropriate to reasoning based on evidences. Zebra must have another inside engine – the belief network engine.

The core of Zebra is the composition of two engines: mining engine (ME) and belief network engine (BNE).

- Mining engine is responsible for collecting learners’ data, monitoring their actions, structuring and updating TLM. Mining engine also provides important information to belief network engine; it is considered as input for belief network engine. In short, mining engine creates TLM by applying mining algorithms, for example, it is possible to model users’ learning path by using sequential pattern mining. Mining engine has another important functionality that is to discover some other characteristics (beyond knowledge and learning styles) such as: interests, goals, learning context… This functionality is the extension of Zebra in future.

- Belief network engine is responsible for inferring new personal traits from TLM by using deduction mechanism available in belief network.

Zebra provides communication interfaces (CI) that allow users to see or modify restrictedly their TLM. Adaptive applications also interact with Zebra by these interfaces. Communication interfaces are implemented as web services used widely on internet. According to World Wide Web Consortium, a web service is defined as a software system designed to support interoperable machine-to-machine interaction over a network. It has an interface described in a machine-processable format (especially WSDL). Other systems interact with the Web Service in a manner prescribed by its description using SOAP messages, typically conveyed using HTTP with an XML serialization in conjunction with other Web-related standards. When complying with web service standard, it is possible to publish CI(s) on internet for third-parties to communicate with Zebra more effectively.

There is external program so-called observer having responsibility for tracking learners’ actions. Observer catches and delivers user observations to Zebra. Observer interacts with Zebra through CI.
2.3. The interaction between Zebra and adaptive applications

Zebra aims to support adaptive learning applications; so in this section we should glance over what adaptive applications are and discuss about how Zebra interacts with such applications. The most popular adaptive learning system supporting personalized learning environment is AES (Adaptive Education System). Here, AES is regarded as an example for illustrating prominent traits of adaptive learning system. The origin architecture of AES has four components:

- **Resource component**: contains learning resources (lecture, test, example, exercise...) and associated descriptive information (metadata).
- **Domain component**: constitutes the structure of domain knowledge so-called domain model. Domain model was often shown in the form of graph.
- **Adaptation component**: is the centric component which gives effect to adaptation. It contains **content selection rules** and **concept selection rules**. We apply content selection rules to choosing suitable educational resources from resource domain (component). On the other hand, concept selection rules are used to choose appropriate concept from domain. These rules must obey user model so that the selection gets correct.
- **User Model**: information and data about user.

We propose the new approach in which the **user model** is removed from AES and becomes the TLM managed by the user modeling system Zebra. Now AES owns only three components: resource component, domain component and adaptation component. The reason is that learner model (TLM) becomes too complex to be maintained by AES and AES should only focus on improving adaptation process and the performance of system will get enhanced when AES takes full advantage of functionalities of Zebra.
All operations relating TLM are executed by Zebra instead of AES. AES interacts with Zebra via communication interfaces according to SOAP protocol. Figure 6 shows the new architecture of AES and the interaction between AES and Zebra. There are only three instances of communication interfaces but the number of them is not limited in practice.

The adaptation process performed by adaptation components includes two main sub-processes: concept selection process and content selection process.
- In concept selection process, concept selection rules are used to match learners’ knowledge to concepts in domain model. In other words, these concepts are filtered to find ones which is necessary for learners to learn in their course.
- In content selection process, learning resources are selected from resource component based on content selection rules that match learners’ learning styles to attributes of resources in resource space. In other words, this process finds the resources that learner preferred or suitable to learner.

The adaptation process includes following steps:

- **Step 1**: The projection of domain model onto knowledge sub-model by using concept selection rules results in a set of domain knowledge called A that student has to learn. This is concept selection process.
- **Step 2**: A is used as filter to choose a set of learning resources called B that relating to A.
- **Step 3**: The projection of B onto learning styles sub-model by using content selection rules results in a subset of learning resources (lectures, exercises, test…) called C tailoring to learner’s preferences. This is content selection process. C is considered as a set of recommendation resources.
- **Step 4**: C is show in content presenter. Presenter can be human-machine interfaces, web sites, learning management system (LMS), teaching support applications…
- **Step 5**: Learner study C by interacting with content presenter.
- **Step 6**: Observer monitors learners in order to catch and delivers learner’s observations to Zebra. Zebra uses such observations to update TLM.

![Figure 7: Steps in adaptation process](image)

### 3. Conclusion

In this paper, the “Triangular Learner Model (TLM)” composed by three underlying characteristics: knowledge, learning style and learning history aims to cover the whole
of learner’s information required by learning adaptation process. Hence TLM has three sub-models: knowledge sub-model, learning style sub-model and learning history sub-model which are considered as three apexes of a triangle.

UMS which builds up and manipulates TLM so-called Zebra includes the core engine and a set of communication interfaces. The core engine is the composition of two sub-engines: mining engine and belief network engine. Mining engine applies data mining algorithms into discovering and structuring TLM. Belief network engine is responsible for inferring new personal traits from TLM by using deduction mechanism available in belief network. Communication interfaces allow users to see or modify restrictedly their TLM and adaptive applications also interact with Zebra through them. We also propose the new architecture of AES (Adaptive Education System) that interacts with Zebra.

References

Designing for Learning with Theory and Practice in Mind

Patricia CHARLTON, George D. MAGOULAS, and Diana LAURILLARD
London Knowledge Lab, University of London, UK
{patricia, gmagoulas}@dcs.bbk.ac.uk; d.laurillard@ioe.ac.uk

Abstract: Our analysis of a number of learning design tools, user studies, gathering user requirements from teaching practice, learning design and instructional design theory, has identified a gap that exists between the user requirements and the tools that have been created, which limits the use of tools and their adoption in everyday practice. To bring theory and practice together requires combining cohesively the results of knowledge engineering modelling with the functional requirements based on human factors around learning design practice. In this paper we will illustrate our design approach, which uses a number of classic design methodologies, to elicit both the theory and practice requirements, and to keep both theory and practice in mind during the design. This will enable the creation of the next generation learning design tools by supporting the appropriate use of theory within practice.

Keywords: Learning design, knowledge engineering, human factors, design methods, learning theory, instructional design theory.

Introduction

There are many tools available that have been created to assist users in the creation of learning designs. They offer different functionality to the user, and are often designed using a user-centred approach that takes into account human factors, or a more technical approach that employs knowledge engineering methodologies. A human factors approach is where the designers gather a set of user requirements, usually from semi-formal interviews, based on the users approach to the actual practice of creating learning design. A classic knowledge engineering approach, often used by AI practitioners to create a design of a theory and model e.g. an inference system, creates a deep dive into understanding theory, and thus concepts and axioms are elicited to create inferences about particular knowledge.

While many tools have been built and are used, we have observed a number of limitations reported from the research literature and our own user studies. After our analysis of a number of tools and user studies gathering user requirements that were driven both from practice and theory, it appears that the gap that exists between the user requirements and the tools that have been created limits their use. Alleviating this situation requires bringing theory and practice together by combining cohesively both results of knowledge engineering modelling and functional requirements based on human factors around design practice. This observation lies at the core of our design approach which is described in this paper.

Our approach uses a number of classic design methodologies to elicit both the theory and practice requirements. To do this we draw from both knowledge engineering and human factors methods on understanding the learning design process, the relevant concepts and theory. Before putting forward our approach we will outline
and evaluate some of the existing tools. We will explain what we mean by learning design and pedagogy approach and the importance of theories as part of tools. Finally, we provide a simple example that illustrates how a learning design expert saw clear steps in articulating the potential use of theory in the learning design process.

1 Learning Design and Instructional Design Theory

Although the term “Learning Design” (LD) has been in use only in recent years, the earliest work in the field can be traced back to “instructivist” approaches, (e.g.[1]; [5]), which provided a clear instructional sequence for teachers to follow. The recognition of the need to make theoretical findings readily available to practitioners led to extensive work on Instructional Design Theory [9], which attempted to make learning theories more operational. However, the later focus on “constructivist” theories of learning presented more of a challenge to an operational approach.

The development of interest in “Learning Design” as a focus of research began with the realisation that the constructivist pedagogical theories were not easily embedded in the practice of teaching [3]. The emphasis on what learners were doing, and how to support their activities, was much less constrained by constructivism, and therefore created a degree of uncertainty about the way it would work in specific contexts. This dependence on the context in which learning takes place required an approach to teaching based on design principles rather than pre-defined instructional sequences [8].

There have been attempts to offer “toolkits” or software to enable ease of entry into pedagogic design and support non-specialists in engaging with learning theories. Despite the effort, existing e-learning systems and authoring tools have limitations in respect of support provided and usability. They do not accommodate the needs of teachers who increasingly look for more intelligent services and support when designing instruction in order to avoid cognitive overload [19].

Our research into learning design has identified four distinct approaches to learning design tools: standards-oriented, generic, theory-based, and knowledge engineering. The area of research is vast so only a selected set of tools are summarised in Table 1 to illustrate these approaches. There has been a great deal of research to uncover the way learning designers practice, from design creation to delivery. The result of this work, e.g. Masterman [4], helps to understand how on a day-to-day basis the learning designer goes about creating, modifying, sharing and using their products of design, and the many tools available for supporting learning design. This human factors approach focuses on human needs in learning design applications, including systems, workplaces and artefacts, information and communication tools used. The findings reveal some of the resistance and uptake of the current tools and the gaps within the field. Even the very idea of underpinning a tool with theory encounters resistance from user groups. Comments, such as “too prescriptive” or “too constraining” or “inappropriate” are often iterated during the user evaluation at workshops on e-learning or learning design tools.

In our view, the application and employment of different theories may offer the learning designer a better mapping of their cognitive approach to tool usage. In general, while we assume that most learning designers make use of theory, we also assume that this might be implicitly or intuitively used by the designer and thus a tool or environment design requirement needs to identify to the user the theory usage where appropriate. This leaves the control and decisions with the user.
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<td>and content, e.g. LAMS [12], Moodle [13], CompendiumLD [11]. Among those,</td>
<td>certain cases, enable collaboration, online learning and social networking</td>
<td>need to learn and engage with a number of tools to benefit from re-use.</td>
</tr>
<tr>
<td></td>
<td>Phoebe [14] is a purpose-built application that guides teachers through</td>
<td></td>
<td>Despite recent efforts there is still limited interoperability between</td>
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<td></td>
<td>theories that could inform the construction of designs.</td>
<td></td>
<td>tools. They appear “theory agnostic”, as they follow no explicit model or</td>
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<td></td>
<td></td>
<td></td>
<td>theory. Many tasks are user driven which might generate high degree of</td>
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<td></td>
<td></td>
<td></td>
<td>cognitive overload for some users.</td>
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<td>Theory-</td>
<td>Usually support a particular instructional design theory. An overview of</td>
<td>Illustrate that theory-driven learning designs be automatically generated</td>
<td>Instructional designers' context is not included and systems mainly adopt</td>
</tr>
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<td>based</td>
<td>the area is given in [6].</td>
<td>using inference engines that enable sequencing and presentation of</td>
<td>only one theory. Adaptation of designs is complex and requires clear user</td>
</tr>
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<td></td>
<td></td>
<td>instructional material depending on learner characteristics. This form of</td>
<td>models to ensure good cognitive mapping.</td>
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<td>adaptation may enable more effective learning as it may reduce cognitive</td>
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</tr>
<tr>
<td>Knowledge</td>
<td>Ontology-based learning design tools represent domain concepts and</td>
<td>Facilitate communication and sharing of learning design knowledge by</td>
<td>Approaches to date either do not include the explicit use of learning</td>
</tr>
<tr>
<td>Engineering</td>
<td>relationships [2] [7], as well as educational theories and relationships</td>
<td>defining common vocabularies and providing users with rational for</td>
<td>theories within the design or do not formalise this. Most approaches stop</td>
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<td></td>
<td>among them [17].</td>
<td>learning designs use. Enables designing rules of inference or decision</td>
<td>at the modelling stage of a particular approach and do not include how and</td>
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<td></td>
<td></td>
<td>points to assist in the process of creating learning designs</td>
<td>when to use theories in practice.</td>
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</table>
To design such a tool or environment requires the software design to clearly identify and make use of both concepts of theory and practice. It is also possible to offer the designer other approaches and provide examples of approaches to consider other views. However, this requires both the theory and the practice within a tool being cohesive and “context aware” of the user needs.

We summarise below some of the high-level observations from the literature review, our user studies and tool evaluations:

- **Alleviate cognitive overload especially at the early stages of design**: design is creative and will be iterative moving between abstraction and detail depending on the user’s process of problem solving, thus engaging sometimes with theory in detail or abstractly or not at all.

- **Accommodate the needs of a diverse audience**: users’ level of learning design and technology experience differ and their needs and requirements both from tools and learning design support are quite diverse.

- **Better represent the various theories of learning design**: there is currently a variety of approaches, which leads to various interpretations of theories and usage in tools that appears ad hoc and confusing.

- **Evaluate tools and identify their limitations**: the variety of tools available for learning design indicates that these provide added value, nevertheless there are no comparative evaluations of these tools in terms of theory support, agnostic, neutral and their use in practice. At the same time, more tools are being developed suggesting that there are limitations but without stating what they are.

- **Exploit the potential of knowledge-based approaches**: knowledge engineering is very appealing as a methodology for designing tools. However, exploitation of the approach has been very limited to date and little progress has been made. In our view this is a factor that limits the possible usage of theory in the practice of Learning Design.

2. **Towards Design Environments that Support Cohesion Between Theory and Practice**

From our analysis of existing learning design tools and their limitations, we have concluded that a knowledge engineering approach to generating user requirements should form the basis of our methodology. Most learning design tools, if not all, support a predefined structure (e.g. hierarchical, network and so on) about the concepts of a session, activity or course and define some learning outcomes and teaching methods. The process typically involves a knowledge elicitation stage which often focuses on identification of system components and causal links to formulate conceptual models [15]. A typical example is given in [2], where an overview of the stages involved in an ontology-based design approach is provided. Elicitation techniques are generally used for problem definition, model conceptualisation and model boundary definition. However, while this process may yield a domain model it misses a vital step for the inclusion of explicit theory. Another step is also required in order to create a mapping of concepts to information usage. This missed step means that if the model contains the theory, and the practice contains the typical information used, then when to inform a decision within a specific user task by theory or practice is not explicit in the learning design process. This means to understand a learning design
tool’s approach to the use of theory maybe difficult to determine, and thus add a potential burden on the designer to make informed decisions when creating learning designs. To bridge the theory and practice, making explicit the relationship in our design, we have adopted a number of methods. These methods have been used to identify, understand, model and design (coarsely) the following:

- Learning Design Structure (LDS): the most common and frequently used learning design concepts when design a curriculum, course, module, session or activity;
- Conceptual Model of Learning Design Practice (LDP): Creation of a conceptual model and definitions that articulate design practice and context;
- Conceptual Model of Theory (CMT): Creation of a conceptual model and definitions that articulate theory and its usage;
- Knowledge Modelling (KM): Creation of domain ontologies of practice and theory including relationships between concepts of practice and theory.

A summary of the knowledge elicitation and methods used in our design is provided in Table 2. The result of this approach has been used to design and develop our Learning Design Support Environment (LDSE [20]).

<table>
<thead>
<tr>
<th>Method</th>
<th>Purpose</th>
<th>Major advantages</th>
<th>Major disadvantages</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaluation of previous work and findings</td>
<td>Research into evaluations of learning designers’ current practices to</td>
<td>Builds on previous work; Helped to see common approaches of learning designers, expectations and barriers to use.</td>
<td>Assumes previous studies have followed accepted methods. Open to Chinese whispers interpretation.</td>
<td>Informs specification of Learning Design (LD) structure and creation of conceptual models for LD practice. Identify emerging trends by doing our own user studies; further knowledge elicitation helps to alleviate disadvantages. Usage of additional experts and case studies has confirmed those concepts that are highly compelling.</td>
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<tr>
<td>about human factors</td>
<td>identify key concepts (LDS).</td>
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<tr>
<td>Questionnaires</td>
<td>Before interviewing users a number of questions were asked to determine</td>
<td>Structured information about Learning Design approaches used in practice can be identified, which are useful to specify LD structure and conceptual models.</td>
<td>Difficult to confirm that inputs reflect actual user behaviour in learning design practice.</td>
<td>Certain contextual data was either verified or queried for evidence of support. The knowledge was used to create profiles of type of users and further knowledge about barriers to use.</td>
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<td>their current practices (LDP).</td>
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<td>Semi-structured interviews</td>
<td>Workshop where a number of learning designers were asked how they</td>
<td>Confirmed a number of previously identified concepts and expectations. Provided more explicit concepts about “living design artifact” for purposes of sharing.</td>
<td>Time consuming in analysis. Illustrated the use of concepts in different ways.</td>
<td>Convergence on a clear usage and understanding of learning design terms appeared complex if not impossible. Handling different uses of concepts emerged as a strong requirement to assist in addressing cognitive overload and barriers to use.</td>
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<tr>
<td></td>
<td>created their learning designs (LDP)</td>
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<td></td>
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</tr>
<tr>
<td>Method</td>
<td>Purpose</td>
<td>Major advantages</td>
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<td>Outcome</td>
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<tr>
<td>Focus Group task analysis</td>
<td>During the workshop the participants were asked to discuss limitations of current tools and their key requirements (LDP).</td>
<td>Concepts that are used from this method have been supported by previous research findings. Helps obtaining agreed and different views on usage.</td>
<td>No research method to validate results. Can be dominated by an individual.</td>
<td>Confirm concepts identified before. Reveal a new requirement about ease of sharing the designs with students and other practitioners.</td>
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<tr>
<td>Scenarios</td>
<td>Specify types of users and define user context by constructing scenarios in the form of personas Explore information and functional requirements (LDP).</td>
<td>Allows creating a set of example steps in the process of creating a learning design. Allows using different sources for creating scenarios and personas that reflect common set of requirements.</td>
<td>Potentially subjective.</td>
<td>Generating and expanding the general expected set of “practitioners” concepts building on the previous knowledge elicited. Modelling of reasoning process and implicit knowledge when creating learning designs.</td>
</tr>
<tr>
<td>Evaluation of existing tools</td>
<td>Evaluate a general set of “learning design tools” to determine design structure used and use of practice and theory</td>
<td>Facilitates exploration of key features and usage of tools by users. Reveals potential limitations of tools, such as lack of the use of theory within tools, usability issues</td>
<td>Subjective and a thorough analysis is very time consuming.</td>
<td>Illustrating a lack of explicitly used theory described and used meant further knowledge elicitation is needed. Identified the gap between LDS, LDP and theory.</td>
</tr>
<tr>
<td>Knowledge modelling of learning design</td>
<td>Create domain ontology of concepts in practice through concept definition and knowledge elicitation (KM).</td>
<td>Common concepts identified and grounded.</td>
<td>Still focused on practice and little theory included in model.</td>
<td>Exchanges of the domain ontology and iteration created a refinement of the model and identified lack of theory.</td>
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<tr>
<td>Learning design case studies</td>
<td>Gather from experts case examples of usage of theory in the design creation process (CMT).</td>
<td>Clearly identify the points where learning theory may be used. Identify commonly used theories and rationale for use.</td>
<td>Potentially subjective. Illustrated ill-defined concepts.</td>
<td>Iterative knowledge elicitation process between knowledge engineer and the experts that leads to refined concepts and rational for use.</td>
</tr>
<tr>
<td>Method</td>
<td>Purpose</td>
<td>Major advantages</td>
<td>Major disadvantages</td>
<td>Outcome</td>
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<tr>
<td>Knowledge modelling of theory</td>
<td>Identify well-defined and ill-defined terms, taking the rationale from explicitly identified examples given (KM).</td>
<td>Provides identifiable differences between learning theories. Illustrates explicit relationships between learning outcomes, learning theories and activities</td>
<td>Subjective in terms of theory modelling as the individual experts have a different view on theories.</td>
<td>In order to include theory, the concepts are formally expressed. Identification of those aspects that can be formally modelled and question those aspects that are of concern.</td>
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</table>

This approach enabled us to establish the concepts typically used in learning design practice and illustrated the loose way theory was encapsulated both in scenario descriptions and in current learning design products. The theory is tacit knowledge to the expert and ambiguous and diverse in the current definitions. The process of refining the theory model and explicitly identifying with the experts when theory should be used within the process of design is the first step to addressing Wiley’s use of theory in computational models, [10], and may help to address the barriers to use by practitioners.

We used Protégé (http://protege.stanford.edu/) to model the concepts and the relationships of theory and practice. This process of developing the domain ontology enabled us as knowledge engineers to determine the concepts and ideas that were not well defined. The concepts in practice are modelled as part of the domain ontology and are understood in context from using a user-centred methodology of gathering user needs to functional requirements.

Figure 1 is a walk through of a sample case expressed by an expert about how the process of learning design and use of theory work together. This case starts from considering learning outcomes, which is usually a part of creating a learning design. The example was simplified by the expert as she wanted to illustrate the decision steps involved and why they could take place. To arrive at this process, a typical knowledge elicitation approach was used starting from sharing the personas that were generated from the scenarios, capturing relevant human factors. Requirements generated provided the first steps to functional requirements for the system and the interface. The conceptual modelling of LD practice and theory required a different approach. While understanding practice may highlight certain concepts as needed, it won’t tell the design the boundaries or relationships of the concepts or what can be inferred from these concepts.

The personas (descriptions of typical users) illustrated system functionality that was clearly understood and areas that required further investigation. The results of the scenarios influenced the domain modelling but other analysis and research also came into play. The development of the domain model was done in a number of stages. The first was a document of definitions of concepts developed initially by the knowledge engineer. The document created a very shallow taxonomy and left concepts open. This allowed the experts to determine the taxonomy and relationships from their experience but also established the vocabulary that would be shared. This document was used as a means of communication and the ontologies were designed reflecting this, and these were then shared.

The lack of learning theory explicitly modelled led the experts to provide this walk through as it became evident that a deep theory model would be difficult to articulate in
the same way as the general knowledge model of the domain ontology. Figure 1 shows a sequence of decisions and searches a user could make to get to the output of an edited existing learning activity sequence populated with a found learning object. The user may omit these stages, or do them in any order, but omitting a stage will reduce the filtering that can be done on the approaches, or sequences offered.

![Diagram](Image)

**Figure 1.** A simple walk through illustration by an expert. The highlight draws attention to the stages where the user is invited to build on and use existing work created by others. It is the ‘pedagogic approach’ stage that brings in the theory.

The process of Figure 1 provides the decision points that lead to when theory and potential inference may be possible. At the point that a pedagogy approach would be chosen it is expected that the designer knows the topic and aim of the particular program, course, module or some specific instance of session, such as a lecture.

The design of a learning outcomes decision can be assisted with examples. For example, Bloom’s taxonomy [18] can be used to provide examples of the way these may be defined. The selected pedagogic approach links into learning theories. For this initial use of theory, our process of knowledge elicitation has been limited to only four types, didactic, constructivist, collaborative and narrative. The user selects the theory appropriate to their view. From this decision point the designer is given a set of appropriate activities that should be able to meet the learning outcome using the selected theory.

The use case was used by the expert to illustrate the explicit decision links between the learning approaches and sample sequence activities and learning outcomes. This process of use case exchanges between experts is important as this helps the knowledge engineer see the different approaches in the use of learning theories and how these concepts can be differentiated but more importantly provides the experts a method to validate and check their thinking about the process and whether or not they have articulated the decision points of theory usage in the way that seems rational to them. Through shared concepts about the domain and a process which describes where theory is relevant to practice it is possible to identify a domain model of learning theory and the important decision points of where theories are important. These relationships can be modelled; thus designers can select and apply theory as they choose. This supports more the view of Wiley that the designers need to understand theory.

Development of the inference engine is in JESS (http://www.jessrules.com/) as this works well with the protégé ontology model and allows quick prototyping for verifying the concepts with the domain experts.
3. Conclusions and Future Work

As the learning theories can have certain properties and explicit usage in the design, the knowledge engineering approach provides a means of capturing this that allows the experts to further examine and clarify. Capturing the practice in a domain model creates also the advantage of creating a vocabulary that experts can examine and either agree with or express their different views. The process of knowledge engineering, especially with today’s tools, means the domain ontology can be refined until the core concepts formed are agreed. However, it is unlikely that this consensus will be achievable; in spite of that, the opportunity to still use the functionality of the learning design environment but with designer specific concepts is possible. A knowledge-based approach to modelling learning theory is essential for two reasons: (i) to determine core concepts and properties of theories that can be agreed and (ii) to make explicit the relationship between theory and process of learning design, which also requires agreement. This process allows the engineer to know if and when a theory can be applied explicitly and why.

Putting the theory into practice means understanding the learning designer’s typical approach and when theory is “practical”. The literature about user studies to identify the user needs provides support for specifying common requirements and concepts used in learning design. As far as we can tell this is the first piece of research to evaluate a set of tools and approaches to understand the theory applied and the teaching design process used. None of the tools to date have addressed supporting learning theories and practice in such an explicit way as that identified by our project. It is clear that one theory is not sufficient or that only a specific theoretical model without building on practice will work. Without an explicit model of theory we cannot benefit from the use of theory, we cannot evaluate its use, determine the impact or appreciate and thus build on different perspectives and understandings of learning design. The project is at the beginning and evaluation of our approach in the use of theory, application in practice and learning design through a set of user studies will inform us about our next stages of design e.g. concepts, decision steps etc.

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Reference


