Implementation of adaptive learning designs

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Abstract: Designing adaptive learning activities, i.e. activities which provide learner-dependant variant learning experiences, is an inherently demanding pedagogical task. Designing adaptive e-learning activities should not add disproportionate technical difficulties to the task. IMS-Learning Design purports to provide a pedagogically neutral and technically smooth environment for the design of educationally rich, including adaptive, learning scenarios. However, although IMS-Learning Design has been effectively used for adaptive, web-based learning, most teachers and instructional designers consider it to be technically out of their reach. Two examples of IMS-Learning Design compliant adaptive web-based learning activities are presented in this paper to show that this is not really the case. Learner profiling and personalization is achieved in adaptive courseware compliant with the IMS-Learning Design specification, including a diagnostic learning style test and an educational recommender system. These components make use of the learning style and prior knowledge respectively, in order to adapt the presentation of the learning material and the feedback given to the learner.

Keywords: e-learning, adaptive learning, learning design, e-learning standards, IMS-LD, IMS-QTI

1. INTRODUCTION

The work described in this paper is motivated by the fact that an opportunity is being shadowed by a problem: adaptive learning can be managed effectively by the IMS-Learning Design (IMS-LD) specification (the opportunity) which has been criticized as being too technical (the problem). Indeed, the IMS-LD specification has been frequently used for adaptive, web-based learning (see for example (Burgos et al., 2006; Hazlewood et al., 2008), but it has been criticized for being too difficult for non-technical users (see for example: Gómez et al. 2009; Bailey et al., 2006). This restricts the development of IMS-LD compliant courseware to these sub-groups of stakeholders (researchers, teachers, instructional designers) that have a fairly good technical background. An interesting research challenge is to describe potential uses of this e-learning standard for adaptive courseware that do not require much technical knowledge and furthermore, to design, develop and evaluate the courseware.

Learner's prior knowledge (see for example: Görgün et al., 2005) and their learning style (see for example: Chen and Zhang, 2008) are two parameters often referenced in the recent literature being used for adaptation. In a preliminary study reported here that was conducted among ten teachers and instructional designers, it seems that indeed they try to augment the learning experience (both face-to-face and e-learning) using these parameters at a great extent. This paper describes two adaptive components: a diagnostic learning style quiz and an educational recommender system, which are based on the learning style and prior knowledge of the learners, respectively. The IMS-LD specification is being used as the basis of the adaptive method.

The remainder of the paper is structured as follows: the background (IMS-LD and adaptive learning design) is presented in Section 2, followed by the motivation in Section 3; the research methodology (DBR) is outlined and a preliminary survey presented (Section 4); implementation issues follow for both the diagnostic quiz and the recommender system (Section 5). In conclusion, the promise of IMS-LD use on adaptive learning is discussed and future plans concerning the integration with mobile learning and the Sharable Content Object Reference Model (SCORM) e-learning standard are outlined.

Of course, compliance with an e-learning standard does not guarantee achievement of the desired educational goals. Rather, standards mostly provide mechanisms for promoting interoperability, re-usability, accessibility and other 'good utilities' of learning objects or learning activities. Thus, they can be considered as mechanisms that promote quality in e-learning, though not necessarily in learning.

2. BACKGROUND

2.1 The use of e-learning standards: IMS-LD and IMS-QTI

IMS-Learning Design (IMS GLC,2003), a de-facto e-learning standard, is a pedagogically neutral specification in that it provides a formalization of the teaching-learning process through the metaphor of the theatrical play (Jeffery et. al, 2005), leaving all the pedagogically vital decisions, such as teaching strategies, learning objectives etc, to the instructional designer. Moreover, IMS-LD is especially designed for web-based learning and facilitates interoperability among LD systems and tools, since it provides a "platform-independent notational convention to allow sharing and re-use of the learning designs" (Britain, 2004) and bridges the "gap between usability of current generation of tools and user abilities and expectations" (CETIS, n.d.). It enables reusability of a learning design (i.e. learning scenario) as a whole or parts of it (Jeffery et al, 2005).

The IMS Question & Test Interoperability (QTI) specification (IMS GLC, 2005) describes a data model for the representation of questions, tests and their result reports. It enables sharing of test items and result data among authoring tools, learning systems, e-portfolios, e-assessment systems etc. Additional related information, such as outcomes, grades and associated metadata can be also transferred between compliant systems.

2.2 The use of the IMS-LD specification for adaptive learning

One of the first attempts towards providing personalized web-based learning through the use of IMS-LD compliant Units of Learning is being described in Halm and Towle (2005) where the following adaptation strategies are discussed:

- Using different communication and interaction channels such as synchronous interactions (chat) for extrovert learners vs. asynchronous interactions (forum) for introvert learners.

- Deploying different cognitive strategies, such as deductive (rule–example) vs. inductive (example–rule). Exploratory learners may benefit more by concepts being introduced through examples, whereas for other learners a definition may be the better introduction of a new concept.

- Exercise different levels of learners' encouragement. This was a strategy "where the feedback a learner receives is tailored to their learning orientation" (Halm & Towle, 2005).

A recent literature study conducted for the Grapple project (http://www.grapple-project.org) concluded on seven types of adaptations in e-learning systems and the extent to which IMS-LD can support each one:

Table 1. Support levels of the adaptation types

Type of adaptation	Related to	Level of support
Interface-based adaptation	elements of the graphical user interface	None
Learning – flow adaptation	the sequence of the learning activities	Full
Content-based adaptation	changes of the actual content	Full
Interactive problem-solving support	guidance that helps the user to take a step further in solving a problem	Full
Adaptive information filtering	appropriate information retrieval	None
Adaptive user grouping	ad hoc creation of groups of users	Partial
Adaptive evaluation	changes (of the actual content etc) based on learner's performance	Partial

Combining the results of the two approaches one may conclude that there are three levels of difficulty in designing adaptive, IMS-LD compliant Units of Learning:

- Level 1: one adaptation strategy

- Level 2: overlapping adaptation strategies that are fully supported by the specification

- Level 3: overlapping adaptation strategies not (all of them) fully supported by the specification.

3. MOTIVATION

A significant advantage of using the IMS-LD specification for adaptive learning is that there is no need to re-create the runtime environment for the adaptive courseware, since this infrastructure is implicitly inherited in any IMS-LD compliant player (Halm & Towle, 2005). Accordingly, there is no need for the developers of the adaptive courseware to bind themselves with a particular authoring tool: any level-B compliant IMS-LD editor will do. Level B provides the key functionality for adaptation in Learning Designs, namely properties and conditions. More specifically, it enables a simple "key-value pairs" (like "Age"= 33) type of adaptation (Baldauf et al., 2007) through mappings (rules) between properties and conditions. Level B extends level A, as outlined below (IMS GLC, 2003):

- Level A defines the core components of the Learning Design: roles, activities and environments (which consist of: learning objects and learning services such as forum, and chat).

- Level B defines additionally the properties of the core components and conditions. The conditions may trigger events like: hide/show an activity, initiate a learning service etc.

An example of such an adaptation rule might be the following:

“If the learner is familiar with the topic, then show activities X, Y and Z else show activities B and W”.

In order to implement such a rule in the context of an IMS-Learning Design compliant Unit of Learning (UoL), the instructional designer should perform the following steps:

1. Define a property corresponding to the level of familiarization of the user. The value of this property might be inferred (for example, from the score in a diagnostic test) or declared by the user herself and
2. Create a condition to guide the learner to one of the alternative learning paths.

Below you can see the implementation of this condition using an IMS-LD editor. The figure would be very similar using any IMS-LD editor; the choice of the tool doesn’t affect the implementation complexity.

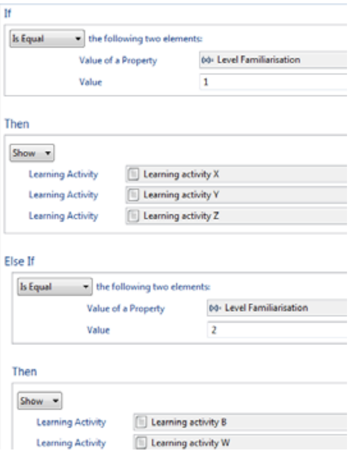

Fig. 1. A simple adaptation rule using the IMS-LD notation

The corresponding code snippet that realizes the adaptation rule in an IMS-LD runtime environment is generated automatically by the editor and it is shown in the box below. Again, the code remains the same irrespectively of the IMS-LD editor used.

```
<imsld:conditions>
     <imsld:if>
      <imsld:is>
       <imsld:property-ref ref= “level-familiarization " />
       <imsld:property-value>1</imsld:property-value>
      </imsld:is>
     </imsld:if>
     <imsld:then>
      <imsld:show>
       <imsld:learning-activity-ref ref="learning-activity-X" />
       <imsld:learning-activity-ref ref="learning-activity-Y" />
       <imsld:learning-activity-ref ref="learning-activity-Z" />
      </imsld:show>
     </imsld:then>
     <imsld:else>
      <imsld:if>
       <imsld:is>
        <imsld:property-ref ref="level-familiarization" />
        <imsld:property-value>2</imsld:property-value>
       </imsld:is>
      </imsld:if>
      <imsld:then>
       <imsld:show>
        <imsld:learning-activity-ref ref="learning-activity-B" />
        <imsld:learning-activity-ref ref="learning-activity-W" />
       </imsld:show>
      </imsld:then>
     </imsld:else>
</imsld:conditions>
```

The developer of the adaptive courseware doesn’t need to write any XML or other code to create an adaptive Unit of Learning (UoL), another affordance of the IMS-LD specification. The simple example above does not include sophisticated adaptation rules; changing it to contain adaptation strategies like the ones mentioned in Section 2 is straightforward. Our research is further motivated by the following: why do the non-technical instructional designers seem to find the process cumbersome? In Halm and Towle (2005) it is mentioned that although creating one simple adaptive strategy might be an easy task, combining different adaptive strategies that may overlap in a learning activity might be a much more demanding task. Another motivation is to explore the possibilities of extending the use of IMS-LD for contextual and mobile learning purposes. The challenge in the latter is “the development of methodologies […] already adopted in desktop-based learning and adapt it to suit mobile environments” (Berri et al, 2006).

4. RESEARCH METHODOLOGY

4.1 Design-based research

In Design-Based Research (DBR), the design of educational intervention starts with the definition of a meaningful problem for the practitioners and requires their collaboration in order to produce domain theories or a design framework or methodologies (PEER group, 2006; Wang & Hannafin, 2005). This paper acknowledges the problem of having a mechanism –the

IMS-LD specification for web-based learning- which may be optimal for adaptive learning but, on the other hand, is cumbersome for non-technical users. For this purpose, it proposes design methodologies i.e. practical guidelines on "how to implement a set of designs, what kind of expertise is required and who should provide the expertise" (PEER Group, 2006).

4.2 The preliminary survey

The table below shows the answers of ten participants who answered, through an online questionnaire in a 5-point Likert scale, the extent to which they adapt their teaching practices according to certain parameters (1 meaning "totally disagree" to 5 meaning "totally agree" with the statement "I adapt my teaching practices according to these parameters"). The participants' occupations (6 from Greece, 1 from Portugal, 1 from Malaysia, 1 from Cyprus and 1 from USA) were either instructional designers and/or educators teaching in schools. All answers but one (who gave grade 2) ranked learning style as an important or extremely important parameter (gave grades 4 or 5).

Table 2. Descriptive statistics

	N	Mean	Std. Dev
Prior knowledge	10	3.90	1.197
Learning style	10	4.00	.816
Learning strategy	10	4.30	.949
Time availability	10	4.00	.943
Learning objectives	10	4.10	.994
Valid N (listwise)	10		

A follow up discussion through a semi-structured interview aiming to elaborate on the answers of the questionnaire revealed that this educator would also like to incorporate learning style as a defining parameter for his teaching practices, if suitable tools were available. In conclusion, it seems that learning style is a determining parameter.

As one participant mentioned during the follow-up discussions: "I think that the teaching process is not far away from a successful theatrical play. You can't play every day the exact same performance for a different audience. You must check the audience response, have a great variety in the repertoire and adapt according to your audience. Repeating the exact same play again and again is not theatre, it is called cinema."

Being itself a metaphor of the theatrical play and providing through this metaphor a formalization of the teaching-learning process, the IMS-LD specification can sustain effectively strategies for adaptive learning.

5. OUR ADAPTIVE LEARNING SCENARIO

The learning scenario that was implemented with the use of the IMS-LD specification consisted of five phases, each containing numerous learning tasks:

1. Diagnostic evaluation concerning prior knowledge and learning style
2. Presentation of the new knowledge
3. Test new knowledge
4. Synthesize knowledge and reflect
5. Apply knowledge

The diagnostic learning style quiz was implemented in the first phase and the educational recommender system in the third phase, for the development of which no technical knowledge is required, since the needed work is graphically represented and designed at an abstract level. The detailed description of the learning scenario is out of the scope of this paper. In brief, in this specific learning scenario, the learning process follows a deductive-inquisitory approach since it presents information to the learners and then the learners themselves produce complete examples of work as assignments. The learning scenario uses various categories of adaptation (adaptive learning flow/content, adaptive grouping, adaptive feedback and adaptive evaluation) that were needed in order to support the learning goals. Web2.0 tools were also used to support collaboration and reciprocity and SCORM compliant learning objects to present the learning materials.

6. DEVELOPMENT AND IMPLEMENTATION OF THE DIAGNOSTICE LEARNING STYLE QUIZ

The development of this test follows a well-known and widely-accepted VARK (visual - auditory - read / write - kinaesthetic) quiz, which consists of a set of 16 multiple response questions (Fleming, 2011). For each question the learner may choose one or more options and even omit a question. When the test terminates, the learner is presented with the results and the tutor can also be informed. This may enhance the learner' metacognition as well as help the tutor to provide more personalized instruction. The above scenario may also be used as part of a wider scenario that exploits the results with the use of adaptive content: for example, the same learning resource, with or without audio narrative. Technically this is possible through the use of 'div classes' in XHMTL documents that show or hide elements (like an audio recording or an image) on a conditional basis (see (Burgos et. al, 2006; Santos et al, 2008).

A research question that needs to be taken into account in this point of the learning design is related to the balance between using information and media in a way that makes most sense to the learner so as to provide differentiated learning on the one hand, and, on the other, according to the theory of multiple intelligences (Gardner, 1983), engaging all the learners with a variety of methods and media. This decision would inform the next stage of the learning design that involves the presentation of the new knowledge.

As mentioned, the IMS-LD specification leaves all the important decisions up to the instructional designer. The authors decided to provide adaptive presentation of information (e.g. show/hide an image or an audio narrative etc) only if there is clear indication concerning the dominant learning preference. Otherwise, the learning materials are presented 'as-are' along with all their media elements. The VARK test provides an algorithm to reveal whether a learner has one clear preference or she is a multimodal learner. The test that was implemented simulates this algorithm through the combined use of properties and conditions, as defined by the IMS-LD specification. Thus, the first module of the Unit of Learning is comprised by the VARK test, following by the presentation of the new knowledge in an adaptive (in case of a single preference) or a non-adaptive mode (in case of a multimodal learner). In figure 1, a snapshot of the results is shown involving a learner whose primary learning preference is kinesthetic, but according to the quiz algorithm, she is a multimodal learner, so no adaptation will take place in the subsequent steps of her learning path.

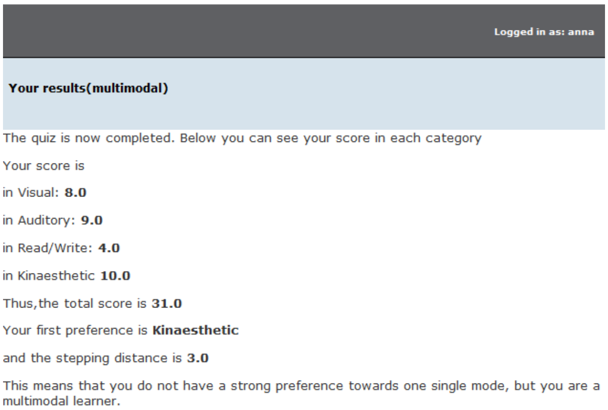

Fig. 2. The results of a multimodal learner

7. THE EDUCATIONAL RECOMMENDER SYSTEM

Moving to the second phase of the learning scenario, the learners are presented with a number of learning activities (ranging from 0 to 8, depending on the level of their prior knowledge and experience) in the use of a specific e-learning authoring tool. First, they evaluate themselves on their prior knowledge in a 5- point Likert scale and the tutor is informed about it as well. The learning activities are basically a set of "How-To's" presenting the key functionality of the tool that the course is about. The final goal is to synthesize their knowledge and implement a showcase (i.e. a complex task) using the authoring tool. Prior to that, the instructional designer has created as part of the learning strategy a 'relevancy matrix' between the pool of the "How-To's"(H) and the pool of the "Showcases"(S), which is shown below.

Table 2. Associations between "How-To's" and "Showcases"

	H1	H2	H3	H4	H5	H6	H7	H8
S 1		X	X			X	X	
S 2	X		X	X		X		
S 3	X		X					X
S 4	X				X	X		
S 5	X	X				X	X	
S 6			X		X	X		

From the table 2, we can assume that some "Showcases" are more demanding than others. For example, "Showcase 7" is a more demanding task than "Showcase 3", since the former demands more prior knowledge than the latter. Thus, we can adapt the difficulty of the learning activities to the learner's prerequisite knowledge.

Between the phase of the presentation of the prerequisite knowledge (i.e. "How-To's") and the synthesis of the showcase on behalf of the learners, there is an extra phase which consists of a quiz. The goal of the quiz is to conclude on the learners' actual prior knowledge. Thus, in the lesson plan, there exists another matrix that re-lates the questions with the "How-To's". So literally, the "How-to's", the questions and the "Showcases" are interrelated. The recommender system, using properties and conditions of the IMS-LD specification (Level B), combines these relations, calculates a 'contiguity grade' for each "Showcase" based on the learner's answers and proposes to the learner specific "Showcases". Subsequently, the learner may discuss this suggestion with her tutor and decide whether she should follow it or pick another "Showcase" instead.

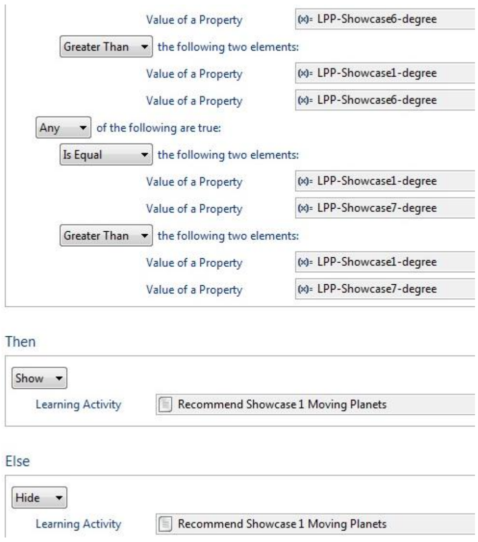

Fig. 3. The use of IMS-LD rules

Figure 3 depicts the idea of recommending the proper "Showcase" after calculating the "contiguity grade" mentioned above. All the needed work is based on the process of setting properties and rules through a graphic user interface, so no technical knowledge (like scripting or XML knowledge etc) is needed, irrespectively of the IMS-LD compliant editor being used.

8. OVERALL LEARNING STRATEGY FOR ADAPTIVE LEARNING & EVALUATION FRAMEWORK

For the scope of this work, the evaluation framework aims at gauging the effectiveness of the learning strategy for the design of adaptive learning, which is being summarized at the table below and shows how the learning preference informs the design of learning activities:

Table 3. Mappings between learning preferences and the design of learning activities

Learning preference	*Learning activities with:*
Auditory	Recordings, audio narratives
Visual	Diagrams, pictures, flowcharts, slides
Read/Write	Web 2.0 tools (forum, chat, wiki),
open ended questions, lists, essays	
Kinaesthetic	Mobile learning, real-life learning experiences

The learning strategy was inspired by the guidelines of N. Fleming (the creator of the VARK test), but also by current trends in educational technology that have already proved in the wider educational industry their positive effects in the learning process (Web 2.0 tools, mobile learning). It further tries to combine these two strands so that: the selection of the media should not only be in accordance with the learning preferences, but also, in a second level should avoid cognitive load and related effects, like the split attention effect. What remains yet, is to test the effectiveness of this learning strategy. For this purpose, the evaluation framework would provide a 360-degree feedback by taking into account evaluation parameters in each of the three levels: 'traditional' (classroom-based) learning, e-learning, and mobile learning. Through the analysis of the interviews, the interplay of these levels was depicted as shown in the figure below. E-learning is conceptualized as an augmentation of 'traditional' learning in which the use of technology plays a decisive role and mobile learning is conceptualized as an augmentation of e-learning where context conditions (basically the "where", the "who" and the "why", as mentioned in Sariola et al. (2001) and mobile devices also play a decisive role in the teaching-learning process.

9. CONCLUSIONS AND FUTURE PLANS

In the learning design strategy, the kinesthetic addition may not be very useful for the 'traditional' desktop e-learning or for the face- to-face, classroom-based learning, but it might be useful when it comes to mobile learning, something that it is included in future plans. As mentioned in (Fleming, 2011), the kinesthetic type is in favor of field trips and training with real-life examples, which are very much aligned with the philosophy of mobile learning. Exploring the possibilities of the IMS-LD specification for adaptive and mobile learning is an interesting opportunity for future research (Specht et al, 2006). Moreover, future plans involve the integration of four specific SCORM (v1.2) metadata elements that may be also used for adaptive learning:

"cmi.student_preference.audio",

"cmi.student_preference.text",

"cmi.student_preference.speed",

"cmi.core.session_time",

"cmi.student_preference.language".

The mechanism for combining SCORM with IMS-LD is already in place, as described in Tattersall et al. (2006). Finally, the reusable Units of Learning (literally .zip files that are comprised by the learning re-courses and their metadata, and a file that contains the structure of the lesson) that contain the implementations of the diagnostic quiz, the recommender system and the wider adaptive learning scenario can be downloaded from the project website (http://opensoa.ouc.ac.cy).

ACKNOWLEDGMENT

This is an extended and revised version of the paper: "Broadening the Use of E-Learning Standards for Adaptive Learning", Proc. ICWL 2012, LNCS vol. 7558, pp. 215-221, Springer, 2012.

The VARK test is licensed under copyright, Version 7.1 (2011) held by Neil D. Fleming, Christchurch, New Zealand. Permission by the creator of the VARK questionnaire (N. Fleming) should be provided in order to be able to use any VARK copyrighted material. For the authoring of the adaptive Units of Learning the ReCourse Learning Design authoring tool was used (http://tencompetence-project.bolton.ac.uk/ldauthor/).

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