Testing the pedagogical expressiveness of LD

1. Testing the pedagogical expressiveness of IMS LD

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Abstract

The IMS Learning Design specification (LD) was introduced as an answer to the shortcomings of existing learning technology specifications. The main difference with existing specifications is that LD is an abstract, conceptual model that is able to express various pedagogical approaches whereby content can be adapted to personal needs and assessments can be integrated. In this article we evaluate the pedagogical expressiveness of LD by taking a set of 16 lesson plans and expressing them in LD. We use three different methods to identify difficulties in expressing the lesson plans in LD. Difficulties identified included circulating a document within a group, giving instructions prior to the start of an activity, random assignment of a group member to a role, group formation at runtime, creation of an inventory to map pre-knowledge, learning objectives and learning achievements, and a way to communicate information on how to deliver a lesson to a teacher. We did not find situations that were impossible to express with LD. The difficulties found are elaborated and suggestions to handle them are given. The methods used are compared and suggestions are given for further research.

Keywords: IMS Learning Design, Open specifications, lesson plan, educational modelling language

Introduction

The use of technology in education has become common in recent years. Delivery mechanisms used in education are increasingly based on technology. Learning technology specifications and standards are designed to facilitate the creation and use of learning content and support material in such a way that it can be exchanged and reused by others. Outside the domain of education there are several examples which illustrate the advantages of standardisation. For example, DVD is an industry standard for delivering movies to consumers; the MP3 format is a de facto standard used to exchange music; and similarly PDF is a standard for exchanging documents. The benefits of standards for users are evident; consumers can be assured that if they purchase a product outside their domestic market it will still be unusable. However, the educational field has not yet reached this stage of standards adoption. There are a number of open specifications that overlap or only partially cover educational needs and likewise propriety systems that impede the exchange of educational material with other systems than their own.

Educational institutes need to make large investments to set up infrastructure to support the requirements of life long learning, globalisation, and a need to continuously access knowledge. Many education and training institutes are exploring the possibilities of the use of internet-based learning management systems (LMS) for the delivery of courses and curricula. One of the functions of an LMS is facilitating the administrative process that is needed to enrol learners, to assign them to courses and to deal with authentication and authorization issues such as user accounts, passwords or assigning rights to different user roles. Learning technology specifications can be used to describe the educational content delivered through the LMS or to facilitate exchange of learning materials between institutions.

For a long time, the focus of learning technology specifications was on developing specifications for learning objects. A learning object is defined by the IEEE LTSC (2000) as any entity, digital or non-digital, that can be used, reused or referenced to during technology-supported learning. Specifications for learning objects have primarily been designed to ensure interoperability, focusing on technology issues and reuse. The instructional value of learning objects is rarely? discussed.

Most of the open e-learning specifications released for course development and course delivery up to now are limited to a restrictive set of supported pedagogies (Rawlings et al., 2002). If we look at the full spectrum of course development and delivery, most specifications focus on the description of learning objects and meta-data and on sequencing learning objects. The Sharable Content Object Reference Model (SCORM), which is widely used for delivering educational material (Olivier & Liber, 2003) is based on the assumption that learning content can be decomposed into discrete, context independent entities. The result of this narrow focus is that learning is limited to the consumption of content. Teaching is then limited to the art of selecting the right content and putting it in a structured, sequenced way, and of tracking the learner's progress and assessing the acquired knowledge. Meta-data specifications such as Dublin Core and IMS LOM are used to describe elements that are then used to assemble learning objects into 'courses' but they are too limited to describe the interaction between the elements.

There are also other initiatives to describe education, such as the semantic web. The challenge the semantic web seeks to meet is to provide a language that expresses both data and rules for reasoning about data, and that allows rules from any existing knowledge-representation system to be exported to the web. An important question for the educational semantic web is how to represent a course in a formal, semantic way so that it can be interpreted and manipulated by computers as well as by humans. Although our approach may not be considered an offspring of the semantic web approach, it certainly is in line with its tenets. Below, we will present a semantic model that can be described with a formal modelling language, such as UML (Booch et al., 1999; OMG-UML, 2003). The UML class diagrams can be translated to RDF-Schema and/or OWL Web Ontology Language, depending on the richness of the model (Chang, 1998; Melnik, 2000).

To overcome the limitations of existing learning technology specifications and standards, the Open University of the Netherlands developed a specification named Educational Modelling Language (EML) (EML, 2000; Hermans, Manderveld, & Vogten, 2004; Koper & Manderveld, 2004). EML provides a pedagogical framework of different types of learning objects, expressing relationships between the typed learning objects and defining a structure for the content and behaviour of the different learning objects. Based on EML, the IMS Learning Design specification (LD) was developed and released in 2003. Unlike SCORM, LD is able to describe units of learning based on different theories and models of learning and instruction together with the learning objects used, and can be adjusted to personal needs. As such, LD has the potential to describe a far greater array of learning processes than SCORM (see also Lukasiak et. al., 2005).
Current meta-data initiatives are focused at the learning object level. There are no meta-data schemas that describe how learning objects are aggregated and used in a learning environment (Lukasiak et. al., 2005). LD could be interpreted as a form of meta-data specifically for the learning domain. In this context, it would then be used to describe the objects and events in the teaching-learning process. In comparison with other meta-data specifications, it has the added benefit of being able to be read by a machine and displayed to learners in a player.

As yet, little is known about the possibility of expressing current educational practices with LD. This applies to both traditional and more innovative forms of teaching-learning situations. In response, this article examines a number of examples of current educational practice and investigates? Examines? whether they can be expressed with LD. We deliberately chose examples from existing educational practices, firstly because challenging use cases have already be investigated and described in the best practices guide (IMSLD, 2003), and secondly because it is important to identify hurdles which may keep educators and educational designers from using LD to describe their education. Those situations that are difficult or impossible to express with LD are further investigated to see out if a solution can be found. The rationale is that situations for which no solution can be provided might eventually lead to a change in the LD specification.

This article first explains what LD does, and then discusses the design requirements of LD that are applicable to its pedagogical expressiveness. Thereafter we look at the relationship between pedagogical models and LD to establish the focus of this study. The method section first explains how the learning material was selected and subsequently introduces the test methods that were used. The methods used are then further elaborated. The results section reports the findings per method. For the problems identified in the result section, solutions are then provided and conclusions are drawn.

What does IMS LD do?To explain what LD does, we can look at its underlying metaphor: the script of a theatrical play. What we see as a spectator in a theatrical play is a stage, stage properties, and actors (Koper & Olivier, 2004). Usually the stage portrays a scene in which the play takes place, e.g. if the play takes place in the streets of 18th century London, the stage would be decorated with typical 18th century items such as street lights, and the background would show buildings in the style of that time. The actors in the play are given a script containing their lines. Actors cannot however say these lines whenever they want; the script also specifies the order in which the lines must be said. The play may be subdivided into smaller parts called acts. Usually an act deals with just one event or part of the story which is in itself a small play. When an act is finished, the actors usually change and/or the staging is changed. The script combines all the above information and shows the order in which the acts are performed. The act defines which actors have to say what lines, and the staging in which the act takes place.

In LD the play is placed in the *method* section as shown in figure 1 and its function is similar to the theatrical play script. The LD play contains the acts to be carried out in the order listed. An act defines who (which role) has to perform which activity or set of activities. As such, the method is the link between all the components of LD; it coordinates the roles, activities and the environments associated with the activities. All the other concepts of LD are referenced, directly or indirectly, from the method. The role-parts within an act link each role to an activity. The activity provides a description of what each role has to perform and what environment is at its disposal. In an act there can be more than one role active at the same time, as in a theatrical play where there can be more than one actor on the stage at the same time. The activities that are simultaneously performed by different roles are synchronised by the act, meaning that if one of the role-parts finishes an activity before the other role-parts, the next act can only become active if all the role-parts of the previous act are finished unless properties or other more advanced features are used.

```
method
      play*
         act*
            role-parts*
               role-ref
               activity-ref
       conditions
metadata
```

Figure 1. The method section of LD that contains the play (an asterisk * means that an element may occur more than once).

The method section of LD can refer to these components directly or indirectly:

- Roles
- Activities
- Environments
- Notifications

In LD there are two predefined *roles*, a learner role and a staff role. Each one of these roles can be further specialised into sub-roles. For example if the course is about designing buildings, one learner could play the role of an architect and another learner could play the role of a metal construction expert. Similarly the staff role can be sub-divided. Each role can later be assigned to different activities.

Activities in LD are associated with a role in a role-part, and they contain the actual instruction for a person in that role. If the activity is directed at a learner and aims to achieve a specific competence it is referred to as a learning activity. The other possibility is that an activity represents a support activity. Typically, support activities are performed by a person in a staff role, but learners may also be supported by their peers. Furthermore, activities appear as single activities or they can be grouped in structures in a way that they must be carried out sequentially or partially ordered.

Environments are where learning objects and services are located. Learning objects are typically used by learners when performing an activity, but these objects (eg. dictionaries) form no part of the activity description itself. Services are used to provide facilities that are helpful for completing activities. Examples of frequently used services are the conference service and mail service. Environments are linked to activities or activity structures.

```
learning-design
   title
   learning-objectives
   prerequisites
   components
      roles
         learner*
         staff*
      activities
         learning-activity*
            environment-ref*
            activity-description
         support-activity*
            environment-ref*
            activity-description
         activity-structures*
            environment-ref*
      environments
         environment*
            title
            learning objects*
            services*
            environment-ref*
            metadata
method
      play*
         act*
            role-parts*
               role-ref
               activity-ref
metadata
```

Figure 2. The main components of LD Level A.

There are three levels (A, B and C) of implementation and compliance in LD. Level A contains the vocabulary to support pedagogical diversity. All the concepts explained above form part of LD Level A as shown in figure 2. Level B adds Properties and Conditions to level A, which enable personalisation and more elaborate sequencing and interactions based on learner portfolios. Level B can be used to direct the learning activities as well as record outcomes. Level C adds notifications to Level B.

Conditions are placed in the method section and have the form of If-Then-Else rules. The 'If' part of the condition uses Boolean expressions on properties that are defined in the component section. Conditions can be used to fine tune the path a learner can take through a course or to personalise a course against some predefined characteristics. For example, a course can be adapted to a learner's learning style, showing only visual learning objects to visual learners and verbal learning objects to verbal learners. A course can also be adapted to a learner's prior knowledge: if learner x has prior knowledge on topic y then let this learner start with activity z instead of activity b.

Properties are containers that can store information such as a learner's progression in a course (completed activities), a learners' learning style, results of tests, and also learning objects that where added during the teaching-learning process as an outcome of an activity (e.g. reports, papers, video registration of a performance). Properties can be either local or global with respect to the run of a unit of learning. A run means that the generic unit of learning is made concrete for one specific group of learners. Local properties are only available within a run of unit of learning and they can be used to store data temporarily. Global properties are also available outside a specific run of a unit of learning and can be used to store information such as data in a learner's portfolio so that it can be used in another run of a unit of learning.

Besides the condition mechanism, LD Level C also contains a *notifications* mechanism for making new activities available. Notifications can be triggered by a change to a property value, the completion of an activity, or a condition that evaluates to true. The notification makes a new learning activity or a new support activity active for a role or it sends a message to another person. The person who triggered the notification is not necessarily the same as the person who needs to be notified. Notifications can be useful if the input for an activity depends on the outcome of another activity. For example in a collaborative task that is geographically dispersed, the results of a task at location A may be used to perform a task at location B.

The unit of learning

The primary use of LD is to model units of learning (UOL) by including the Learning Design in a content package, such as an IMS Content Package. IMS Content Packages describe their content in an XML document called the 'package manifest'. The Manifest may include structured 'views' into the resources contained in that package; each 'view' is described as a hierarchy of items called an 'organization'. Each item refers to a Resource, which can in turn refer to a physical file within the package. It can however also refer to an external resource. Figure 3 depicts the entire IMS Content Packaging conceptual model.

To create a unit of learning, LD is integrated into an IMS Content Package by including the LD element as another kind of organization within the <organizations> element as shown on the right side of figure 3.

The LD element of the unit of learning includes the elements that represent the conceptual model that was briefly outlined before. The details of all the LD elements can be found in the Information Model document (IMSLD, 2003), together with their behavioural specifications.

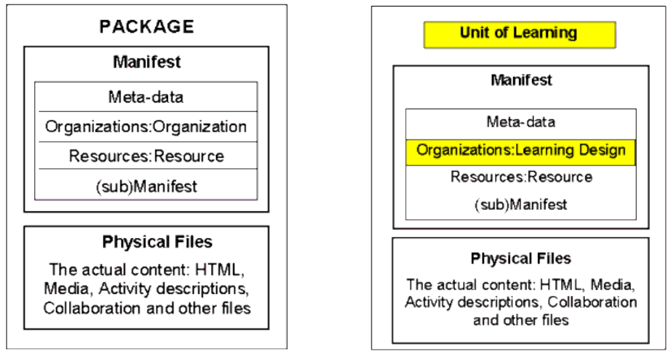


Figure 3. The figure on the left shows the structure of an IMS Content Package. The figure on the right shows the structure of a Unit of Learning, composed by including a Learning Design within the Organizations part of IMS Content Packaging

The concept of LD can be summarised as follows. A person gets a role in the teaching-learning process, this role can either be the role of a learner or staff. For a role, outcomes are stated as learning objectives, these outcomes are to be achieved by performing learning activities for learners, or support activities for those in a staff role. During the performance of activities, if learning objects or services are needed then these are placed in the environment embedded in the activity. Which role has to perform which activity and at what moment in the teaching-learning process is specified by the LD method either through conditions or by means of notifications. The LD model shown in figure 4 is based upon the pedagogical meta-model which will be explained later.

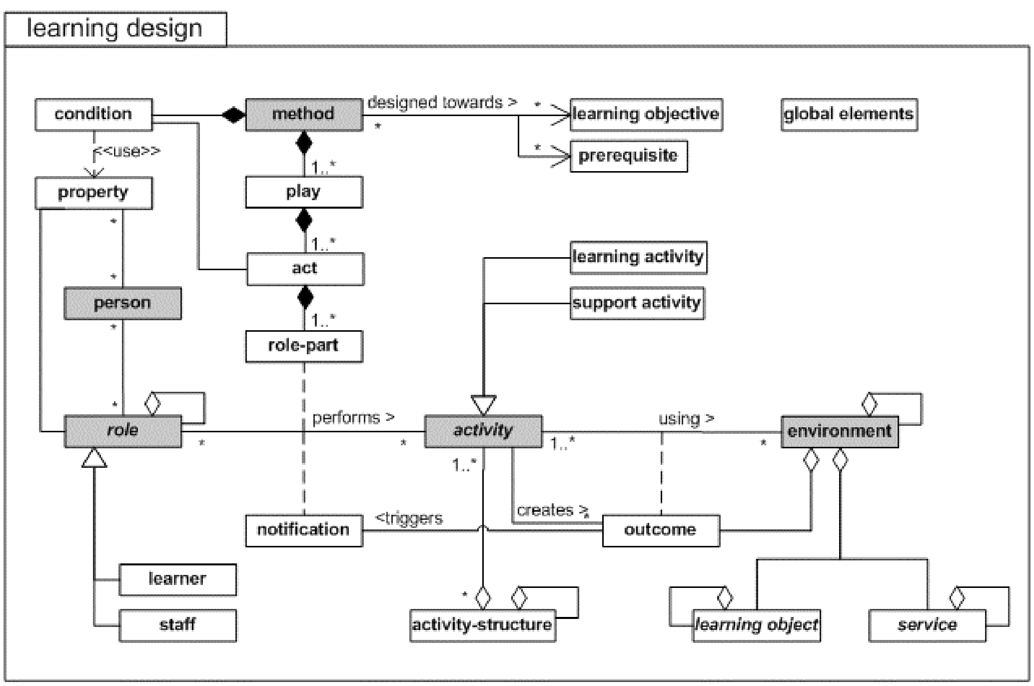


Figure 4. Semantic model representing the learning design of a unit of learning.

Requirement of pedagogical expressiveness

When the Educational Modelling Language (EML, 2000; Hermans, Manderveld, & Vogten, 2004) was developed, an extensive list of requirements was drawn up (Koper & Manderveld, 2004). EML was selected as the base from which to develop the LD specification. Most of the changes made to EML had no effect on the conceptual model (Koper & Olivier, 2004) with the exception of test assessment elements which were removed. LD also has a greater focus on online delivery than EML. We will use some of the original EML requirements to define the meaning of pedagogical expressiveness.

In the set of requirements the three requirements listed below dealt explicitly with the design of education.

(1) The formal language must be able to describe units of learning based on different theories and models of learning and instruction (*pedagogical flexibility*).
(2) The formal language must be able to fully describe a unit of learning, including all typed learning objects, the relationship between the objects and the activities and workflows of all students and staff members using the learning objects (*completeness)*, regardless of whether these aspects are represented digitally or non-digitally.
(3) The formal language must be able to describe personalization aspects within units of learning so that content and activities within units of learning can be adapted based on the preferences, prior knowledge, educational needs and the circumstances of users. In addition, control must be able to be given to the student, staff member, computer or designer as required (*personalization*).

Other requirements dealt with technical issues that are beyond the scope of this article. Pedagogical expressiveness is defined as the ability of a modelling language to describe all types of teaching-learning situations (*pedagogical flexibility*) including the needed flexibility to adapt the UOL to predefined criteria or situational circumstances (*personalization*). The modelling language must be able to describe all learning objects that occur and their relation with the teaching-learning process (*completeness).* To define pedagogical expressiveness, the three requirements stated above will be used.

To evaluate the pedagogical expressiveness of a UOL it is necessary to narrow the definition of a UOL. The UOL itself has no boundaries as to what it can describe. A UOL could be as large as an entire curriculum of a four-year course or as small as just one learning activity of 15 minutes. To define which part of the teaching-learning process will be further investigated, the following section will consider different pedagogical models and how these relate to LD.

Pedagogical models

During the development of EML a pedagogical meta-model was developed. A pedagogical meta-model is an abstraction of pedagogical models. This means that pedagogical models could be described (or derived) in terms of the meta-model. The reason for developing a meta-model was to have a model that was neutral with respect to different approaches of learning and instruction. Neutrality in this context means that specific pedagogical models, like problem-based learning models or collaborative learning models, should be able to be expressed using the meta-model with the same ease.

Models obtained from the literature were studied (see Koper, 2001; Koper & van Es, 2004) in three major streams of instructional theories and models (Greeno, Collins & Resnick, 1996):

- empiricist (behaviourist)
- rationalist (cognitivist and constructivist)
- pragmatist-sociohistoric (situationalist).

These instructional theories have different views on topics such as: knowledge, learning, transfer and motivation. The three streams of instructional theories can be very helpful to map theoretical or practical models of learning and instruction. To evaluate the pedagogical flexibility that was identified above, these three major streams were used. To explain how pedagogical expressiveness was investigated we need to elaborate on the relationship that exists between the LD specification and the pedagogical models as shown in figure 5. The abstract pedagogical models and instances of these abstract models shown on the left side of the figure, are represented by either the UOL schema or parts of the whole schema shown on the right side of the figure. On the horizontal level the abstraction level of the pedagogical models correspond to the UOL schema (instances).

The pedagogical meta-model is an abstraction of pedagogical models and contains commonalities found between several pedagogical models. The pedagogical meta-model is expressed as a Unit of Learning schema containing all the elements of the pedagogical meta-model and restrictions on their usage, as shown in figure 4. The purpose of an XML Schema is to define the legal building blocks of an XML document, like a DTD. An XML Schema defines elements, attributes, child elements, their order and their numberwhether an element is empty or can include text. A schema can also define data types for elements and attributes and default and fixed values for elements and attributes.

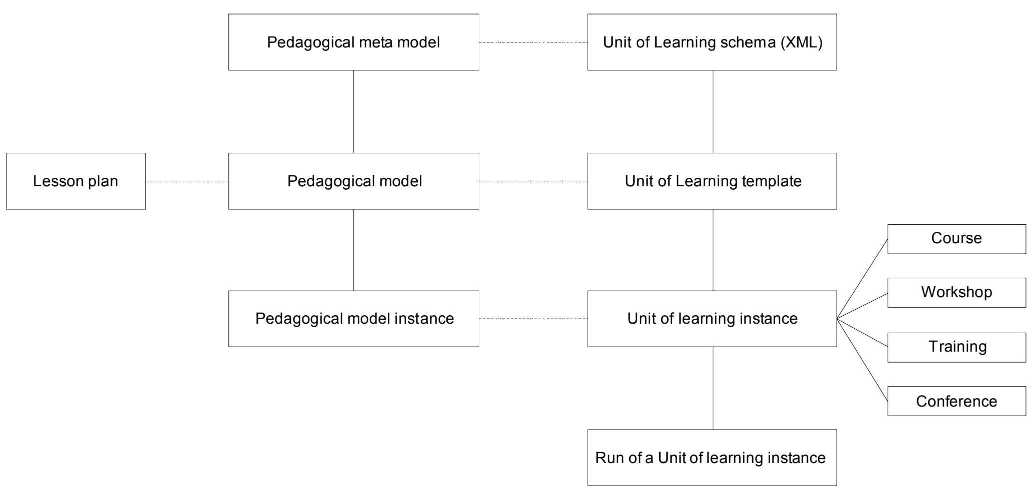


Figure 5. Relation between the pedagogical models and LD.

The LD schema is used to validate instances of units of learning (UOL) that are created with an LD editor. Validation of an instance of a UOL means that the document is checked against the rules stated in the schema, for example that the structure of the document is correct, that multiplicity rules are followed and that references to learning objects and services are correct. Though our intention is to evaluate the pedagogical meta-model represented by the? UOL schema, this approach would not be very fruitful because of the high level of abstraction. Also, the scope of the

UOL schema is too broad to evaluate because only the correctness of an UOL instance is validated, nothing can be said about the meaningfulness of the document for the teaching-learning process. Therefore we must take a closer look at pedagogical models that served as input for the development of the meta-model, and which are expressed at a lower abstraction level.

Pedagogical models were analysed and abstracted to derive the pedagogical meta-model. A pedagogical model is defined as a method that prescribes how a class of learners can achieve a class of learning objectives in a certain context and knowledge domain. Pedagogical models are inspired by theories on learning and instruction. Examples are learning Spanish as a second language, acquiring mathematical skills for engineering, or how to plead in someone's defence during a trial. A pedagogical model can be represented as a Unit of Learning template in XML. Such a template imposes further restrictions upon the Unit of Learning resulting in a structure that is unique for each? pedagogical model. The rules of a template may for example state that a learning activity is always followed by a self-test and a learning activity always has a conference service defined in the environment. By defining a template, course designers are helped to implement a specific type of instruction such as problem-based learning.

Closely related to pedagogical models are lesson plans that also describe how learners can achieve a set of learning objectives but in a less restrictive form than pedagogical models. Lesson plans do not necessarily have a strong relation with learning theories. Teachers who are familiar with a certain topic often create lesson plans for their fellow teachers and may make these publicly available.

A pedagogical model instance is the application of a pedagogical model with specific learning objectives in a specific domain. It is more detailed than a pedagogical model in the sense that content and assignments are made concrete. For a Unit of Learning, this means that resources are added to the design.

A run of a UOL instance implies the concrete assignment of learners and staff to a course and the scheduling of a time and location. If services are defined in the UOL, applications to handle these services are also prepared, with the settings defined in the UOL. If properties are defined in the UOL, instances of these properties are created in the system database and learner portfolios.

Referring again to the theatre metaphor, we can compare the pedagogical model to the complete script that outlines the whole play. An instance of a pedagogical model would then contain the play script, all the stage attributes, the decor, and the lighting. When a run of a UOL is created, it means that the play is programmed for a specific theatre, actors are trained to perform the play, tickets are sold to the audience, and the theatre stage is prepared.

For this investigation, learning material from current education was used. Current education covers all types of education ranging from primary school to higher education and continuing education. To be able to generalise the results, no restrictions were imposed on the type of education. The learning material investigated had to provide enough information so that all the aspects found in the requirements must also be included in the learning material. For this reason we decided upon using lesson plans as learning material for the following reasons. Lesson plans usually describe how a series of lessons or a single lesson should take place. It is expected that curriculum structures are not more complex than those structures used within a lesson. Lesson plans provide guidelines to developers of learning materials based on instructional theories which have a closer relation to pedagogical models than concrete lesson materials. Personalisation is expected to have more impact on materials used within a lesson than on a course or a curriculum.

Method

Selection of learning material

We used English language lesson plans that were available on-line from twelve separate websites (see table 1). The lesson plans offered on these websites covered the full range of education, from kindergarten to university. A total of sixteen lesson plans were drawn at random from the selected web sites, covering various subjects. We chose a random selection in order to get a representative sample of lesson plans currently used in education. Table 2 shows the lesson plan title, subject and a reference to the website from which it was drawn.

Table 1: Websites that offered lesson plans with an approximate number of lesson plans offered and the URL of the web site.

Web site reference	Web site name	Available lesson plans	URL
1	The Gateway to Educational Materials	36,000	www.thegateway.org
2	LessonPlanz.com	300	www.lessonplanz.com
3	PBS teachersource	4500	www.pbs.org
4	Lessonplan search	2300	www.lessonplansearch.com
5	Merlot	9500	www.merlot.org
6	Statistics Canada	400	www.statcan.ca
7	National Grid for learning	190	www.ngfl.gov.uk
8	Teachers.net	1000	teachers.net/lessons/
9	SMETE	300	www.smete.org/smete
10	Knowledge Agora	350	www.knowledgeagora.com
11	Retanet	65	ladb.unm.edu/retanet
12	National learning network materials	70	www.nln.ac.uk/materials

Table 2: Selected lesson plans including the subject the lesson plan covers and a reference to table 1 to indicate the web site where the lesson plan can be found.

Lesson plan title	Subject	Reference
Tongue Twisters	Language arts	2
Lincoln's Secret Weapon	Science & Technology	1
Rhythmic Innovations	Mathematics	3
Consider Copying	Science & Technology	1
The Darien Adventure	History	7
Carnival Safety Success	Language arts	5
Exploring Disability	Drama	2
Ecosystems And Well-Being	Health, Science, Geography	6
Kermit The Hermit	Language arts	1
Inventions	Language arts, Humanities	10
Cracking Dams	Science & Technology	2
The Works Progress Administration And The New Deal	Social studies	3
Learning Microsoft Excel	Science & technology	5
How Do People Express Their Faith Through The Arts?	Social studies	4
Eyes In The Sky	Science & technology	9
A Pittsburgh Memory	Language arts & social studies	13

All 12 websites used subject categories (i.e. mathematics, physics, biology) to present their lesson plans. We followed the procedure as shown in figure 6 to select a lesson plan from one of the web sites.

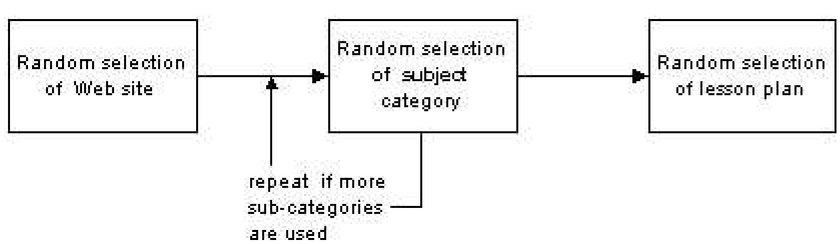


Figure 6. Procedure followed to select a lesson plan from one of the 12 web sites.

For example, first a random number between 1 and 12 was generated to determine the web site to pick the lesson plan from. Assuming the generated number was 1, and then according to table 1 the lesson plan would be taken from the web site of "The Gateway to Educational Materials". That web site used 12 subject categories (see figure 7) to organise their lesson plans.

Tasks

Assign each member of the group a role. Each person has the responsibility to lead the parts of the process listed under their role.
Follow the process below.
Answer the questions on your worksheet as you proceed.
Post messages on the bulletin board as directed, particularly to state your group's position on the dam repair or decommissioning at the end of the quest.

Process

Bookmark the Webquest. You should return to this Process at the beginning of each step. Assign roles.
1. The government has told you that there are problems with the Narrows Dam, so you need to gather some basic information about that dam, which is on the Little Missouri River. Look up the Narrows Dam in the National Inventory of Dams (#). Fill in your worksheet about this dam.
2. Next, you must consider what services the dam is providing and how important these are. Go to the Dams section and read about the societal nature of dams. Fill in your worksheet about the services dams provide.
…

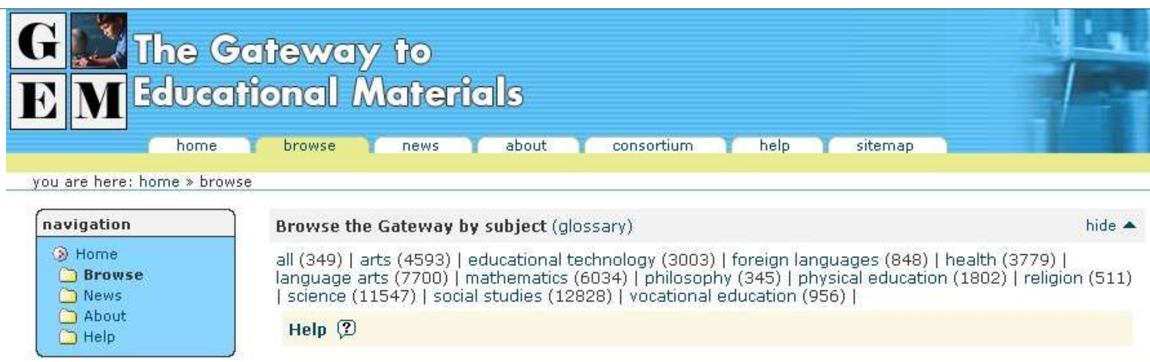


Figure 7. Example of the GEM website with the lesson plans sorted in subject categories.

Figure 8. The list of lesson plans found in the mathematics subject category. This category contains a total of 6034 lesson plans as indicated with the red circle.

Next, a random number between 1 and 12 was generated to determine a subject category, for example 6. The sixth subject category from the list is Mathematics, which contains 6034 lesson plans (figure 8). Finally a random number between 1 and 6034 was generated to determine the lesson plan that would be analysed.

A lesson plan should meet the criteria of having a study duration of at least 1 hour, and contain 2 or more activities. If a selected lesson plan did not meet this criteria, it was replaced by another one using the same selection method.

Methods used to analyse the lesson plans

To investigate whether the selected lesson plans can indeed be expressed fully with LD, we need to elaborate first on what this actually means. A typical lesson plan describes how learners can reach a learning objective or set of learning objectives. A lesson plan is written for a teacher or an educational developer and describes which activities learners and teachers must carry out, the order in which the activities should be carried out, the circumstances under which the activities will be carried out, how learners will be grouped and what materials or technology may be used. A sample lesson plan is shown in figure 9. The whole lesson plan contains an introduction to the problem of the lesson, the tasks a teacher must carry out, a description of the learners roles, process information indicating how learners should proceed through the lesson, a description of materials that may be used or references to required worksheets and some evaluation guidelines for the teacher. These are typical elements for a lesson plan and one can find this information most of the time although the labelling of the information may vary.

Figure 9. Sample of a lesson plan.

We used several criteria to determine to what extent the lesson plans could be expressed in LD. First, it should be possible to make a match between the concepts found in the lesson plans and the conceptual vocabulary of Learning Design (See LD information model; IMSLD, 2003). With these criteria the static structure of the lesson plan is mapped onto LD and if learners or teachers are working on activities in parallel the workflow is synchronised. Second, the workflow laid down in the lesson plan must be realised with either the constructs of the conceptual vocabulary (i.e. acts and role parts) or by using conditions and properties. The use of acts only provides a means to realise a linear workflow. If a more dynamic flow is needed, conditions and properties can be used to change the visibility of most of the elements of the conceptual vocabulary, with the exception of an act. If some kind of adaptation or personalisation was identified in the lesson plan together with elements of the conceptual vocabulary, the addition of properties and conditions should suffice to realise it. Finally, if learners or teachers need to be informed when a certain event takes place, or a trigger is required to indicate that either a learner or a teacher must undertake action, than LD has to provide this.

Several methods were used to analyse the lesson plans. Since this was the first time such an investigation was carried out, we also needed to find methods which were efficient yet would provide all the required information. The methods used aimed at gaining insight into the capacity of LD to express teaching-learning situations, rather than a quantitative measure of the difficulties found. The following methods were selected to analyse the lesson plans:

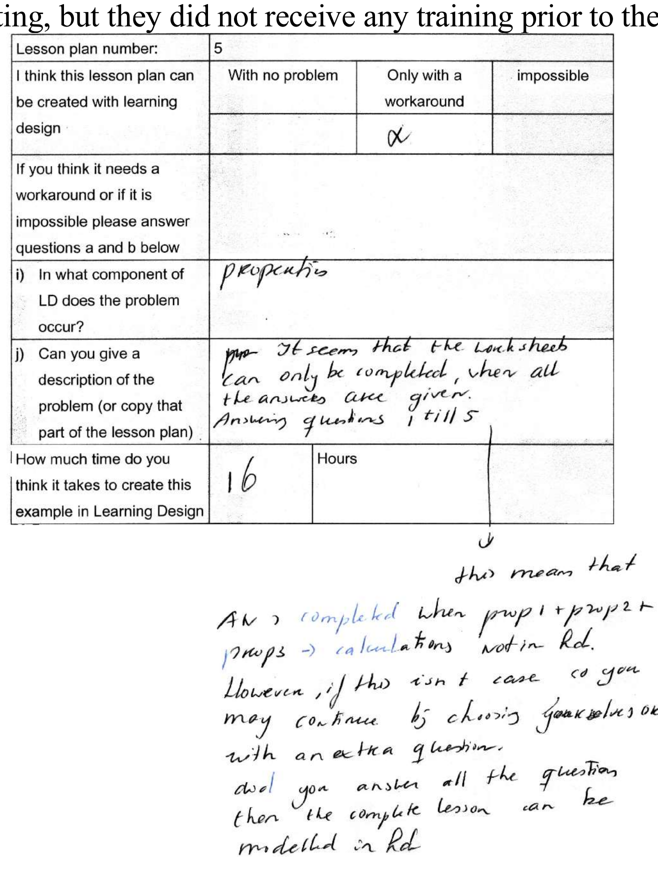
- Expert analysis
- Document validation

- Learning Design coding

These methods highlighted any situation which did not meet one of the criteria. Such a situation could then be labelled as a recoverable error or as a non-recoverable error. A recoverable error was defined as something found in a lesson plan that could not be matched with the conceptual vocabulary; a required condition or property for which there was no clear handle; or a required notification for which no trigger could be provided. A recoverable error can be seen as a weakness in LD that might call for a change or addition to the model. In contrast, a non-recoverable error it is defined as a situation where it was not possible to express a part of a lesson plan with LD at all.

Expert analysis

This analysis method made use of experts that were asked to give their judgement on how easy or difficult it was to create an LD instance of one of the lesson plans. These experts were required to have extensive experience in LD coding and have an awareness of the possibilities the specification offers. For this analysis, we used two LD experts from the Open University of the Netherlands. The experts were asked to rate a lesson plan on a three-point scale ranging from no problems, recoverable error, or non-recoverable error. The experts received brief instructions on how to carry out the rating, but they did not receive any training prior to their rating.



Lesson plan number:	5		
I think this lesson plan can be created with learning design	With no problem	Only with a workaround	impossible
		x	
If you think it needs a workaround or if it is impossible please answer questions a and b below			
i) In what component of LD does the problem occur?	properties		
j) Can you give a description of the problem (or copy that part of the lesson plan)	It seems that the worksheets can only be completed, when all the answers are given. Answering questions 1 till 5		
How much time do you think it takes to create this example in Learning Design	16	Hours	

this means that AW is completed when prop1+prop2+props -> calculations not in LD. However, if this isn't case so you may continue by choosing goalsolves ok with an extra question. and you answer all the question then the complete lesson can be modelled in LD

Figure 10. Example of a lesson plan analysis carried out by an LD expert.

When a recoverable or non-recoverable error was identified, the experts were asked to indicate the part of the lesson plan that led them to their judgement. Figure 10 provides an example of an expert analysis.

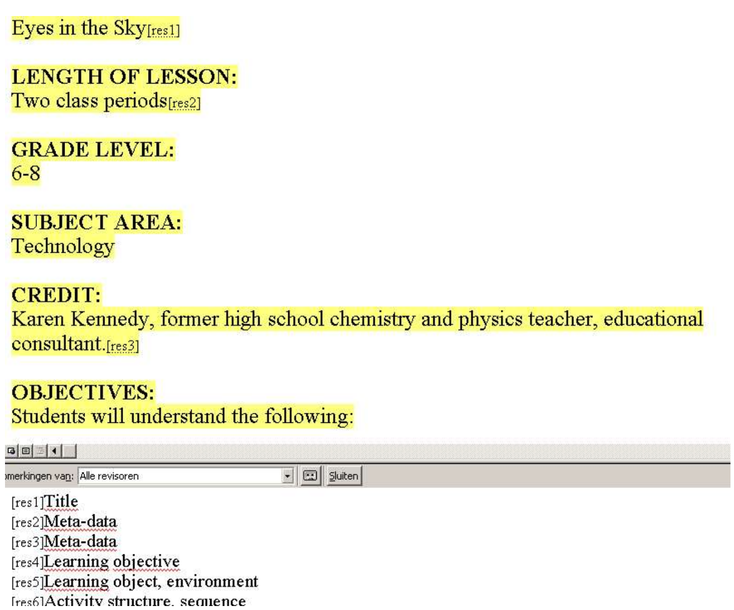
Document analysis

The document analysis method uses a set of procedures to make valid inferences from text. Traditionally, this method has been used in the social sciences to compare texts and search for relationships between them. In this instance, we do not want to compare text documents; we used this method to find similarities between the text in the lesson plan and the LD specification. A central idea in content analysis is that the words of a text are classified into a small number of content categories. (Weber, 1985). Each category may consist of one, several, or many words. Words, phrases, or other units of text classified in the same category are presumed to have similar meanings. The purpose of this content-analysis is to classify parts of a lesson plan according to the vocabulary used in LD. This results in a list of categorised text plus a residue. Residues are thought to be good indicators of a lack of fit of LD.

The procedure followed involved three iterations carried out manually. Firstly, the whole text was read. When text blocks were encountered containing words that could be classified, these blocks would be marked. Secondly, the marked blocks of text were further analysed to classify the text into LD vocabulary concepts. Once the whole text was analysed, the unmarked text became the topic of analysis because that indicated an element that was not available in LD. Further analysis was conducted to reveal if a workaround could be found. A subsection of a lesson plan that was analysed using this method is shown in figure 11.

The analysed lesson plans were also classified according to the main streams of instructional theory (i.e. empiricist, rationalist, pragmatist-sociohistoric). To classify the lesson plans we used the criteria listed by Greeno, Collins & Resnick (1996). They describe instructional theories according to the learning environment in which the learning takes place, the way the curricula are organised, and how learner achievements are measured. The selected lesson plans were rated against the criteria and subsequently assigned to the instructional theory that received the highest rating.

This data was used to investigate the extent to which difficulties in expressing lesson plans with LD are specific to particular pedagogies.


Eyes in the Sky[res1]

LENGTH OF LESSON:
Two class periods[res2]

GRADE LEVEL:
6-8

SUBJECT AREA:
Technology

CREDIT:
Karen Kennedy, former high school chemistry and physics teacher, educational consultant.[res3]

OBJECTIVES:
Students will understand the following:

[res1]Title
[res2]Meta-data
[res3]Meta-data
[res4]Learning objective
[res5]Learning object, environment
[res6]Activity structure, sequence

Figure 11. A fragment of an analysed lesson plan where the upper section shows the original text with text marks referring to the concepts of the LD vocabulary shown in the lower part of the figure.

Learning design coding

The third validation method involved the transformation of the lesson plans into UOLs. To do this we followed the procedure described in the Best Practice and Implementation Guide of LD (IMSLD, 2003). The phases in this procedure are:

1. In the analysis phase, a concrete educational problem (use case) is analysed. The analysis results in a didactic scenario that is captured in a narrative, often on the basis of a checklist.
2. The narrative is then cast in the form of a UML activity diagram in order to add more rigor to the analysis. This is the first design step. The UML activity diagram then forms the basis for an XML document instance which conforms to the LD specification. This is the second design step.
3. This document instance subsequently forms the basis for the development of the actual content (resources) in the development phase. The content package with both the resources and the LD will then be evaluated.

The first phase in the design process was covered by the selection procedure of the lesson plan. Lesson plans provide detailed descriptions of what a lesson should look like. The next phase in the process is the creation of an activity diagram based on the lesson plan. The diagram shows activities organised per actor in so-called swim lanes. In a swim lane, all the activities for a role are listed sequentially. The flow through the whole diagram is indicated by a start node at the beginning and an end node indicating when the lesson is completed with lines connecting the activities. Activities that are placed at the same horizontal level are carried out at the same time but by different roles. An example of such an activity diagram is shown in figure 12.

Figure 12. Example of a lesson plan worked out as an UML activity diagram.

A Learning Design instance was then created from the activity description. During the modelling process, the location and types of difficulties encountered was systematically logged. Figure 13 shows an example of a lesson plan coded in LD. An instantiation of the LD instance could be created and played in an LD compliant player to see the results.

```
- <organizations>
  - <imsld:learning-design identifier="learningdesign1" level="C" uri="http://www.alfanet.portal-ace.com">
      <imsld:title>How environment affects the health of Canadiens</imsld:title>
    - <imsld:components>
      - <imsld:roles>
        + <imsld:learner identifier="WholeGroup" create-new="allowed">
        + <imsld:learner identifier="DeterminantGroup" create-new="allowed">
        + <imsld:learner identifier="DisseasesGroup" create-new="allowed">
        + <imsld:learner identifier="MixedGroups" create-new="allowed">
        + <imsld:staff identifier="Teacher" create-new="allowed">
        </imsld:roles>
      + <imsld:activities>
      + <imsld:environments>
      </imsld:components>
    - <imsld:method>
      - <imsld:play identifier="play1" isvisible="true">
          <imsld:title>Play1</imsld:title>
        - <imsld:act identifier="act1">
            <imsld:title>Act1</imsld:title>
          - <imsld:role-part identifier="Part1a">
              <imsld:title>Part1a</imsld:title>
              <imsld:role-ref ref="DeterminantGroup" />
              <imsld:learning-activity-ref ref="PrepareFactsheet" />
            </imsld:role-part>
          + <imsld:role-part identifier="Part1b">
          </imsld:act>
        + <imsld:act identifier="Act2">
        + <imsld:act identifier="Act3">
        + <imsld:act identifier="Act4">
        </imsld:play>
      </imsld:method>
    </imsld:learning-design>
  </organizations>
+ <resources>
</manifest>
```

Figure 12. Example of a lesson plan coded in LD.

Results

Expert analysis

Two experienced Learning Designers were asked to estimate the level of difficulty experienced with expressing a lesson plan in LD, using a three-point scale. The estimation of options the experts had were (a) no problem, (b) recoverable error, (c) non-recoverable error. The initial rating results showed only a slight inter-judgement agreement (Cohen's kappa $\kappa < .21$) between the experts. Analysis of the comments the experts provided along with their judgement revealed that one expert estimated all classroom-based lesson plans as lesson plans with a recoverable error. If a lesson plan was judged as having a recoverable error based only on a classroom situation then it was recoded as having no problem, because LD is not limited to on-line or distance education.

The inter-judgement agreement for the experts was substantial (Cohen's kappa $.61 < \kappa < .8$) after the data was recoded and is shown in table 3. The experts estimated that it would be possible to express all the lesson plans in LD. The category of ‘non-recoverable error’ is therefore not shown in the table.

The experts agreed on three of the five recoverable errors identified in the lesson plans, with each expert finding one additional recoverable error on which they did not agree.

Table 3: Difficulty to express a lesson plan based upon the expert analysis.

Lesson plan number	Expert 1		Expert 2		Expert agreement
	No problem	Recoverable error	No problem	Recoverable error	
1		x	x		
2	x		x		x
3	x		x		x
4		x		x	x
5	x		x		x
6	x		x		x
7	x		x		x
8		x		x	x
9	x		x		x
10	x		x		x
11	x		x		x
12		x		x	x
13	x		x		x
14	x		x		x
15	x			x	x
16	x		x		
Total	12	4	12	4	14

Document analysis

In total five recoverable errors were found with the document analysis; non-recoverable errors where not found. The results of the document analysis are shown in table 4. The non-recoverable errors category is not shown.

Table 4: Difficulty to express a lesson plan based upon the document analysis and classification of a lesson plan to an instructional stream

Lesson plan number	Error type		Instructional stream		
	No problem	Recoverable error	Empiricist	Rationalist	Pragmatist-sociohistoric
1		x	x		
2		x		x	
3	x		x		
4		x			x
5	x			x	
6	x		x		
7		x			x
8	x				x
9	x		x		
10	x				x
11	x				x
12	x				x
13	x		x		
14	x			x	
15	x			x	
16		x		x	
Total	11	5	5	5	6

Pedagogical flexibility

The difficulties in expressing the lesson plans in LD were categorised according to the major streams of instructional theories as shown in table 5. These data were not analysed further because the number of observations were too small to obtain sufficient power for statistical tests.

Table 5. Difficulties expressing lesson plans in LD, organised according to major streams of instructional theory

Stream of instructional theory	Error type	
	No problem	Recoverable error
Empiricist	4	1
Rationalist	3	2
Pragmatic-sociohistoric	4	2

Learning design coding

During the coding of the lesson plans, the same difficulties expressing a lesson plan in LD were found as during the document analysis (table 6). Occasionally, differences were found with the document analysis but these differences were related to the interpretation of the lesson plan work flow rather than with the ability to express part of the lesson plan in LD. These differences were not systematically logged.

Table 6: Difficulties found during the lesson plan coding

Lesson plan number	Error type	
	No problem	Recoverable error
1		x
2		x
3	x	
4		x
5	x	
6	x	
7		x
8	x	
9	x	
10	x	
11	x	
12	x	
13	x	
14	x	
15	x	
16		x
Total	11	5

Solutions to the identified problems

The results of the test showed that some of the selected lesson plans contained elements for which LD did not provide a standard solution, and an adequate way to describe such cases is required. No evidence was found that LD was not suitable for describing contemporary education, since no situations were found to be impossible to express using LD. It is of interest to take a closer look at those situations that were not possible to describe directly with LD. All cases with a judgement 'recoverable error' either in the document analysis or in the expert analysis will be discussed next and a suggestion for how to code these cases is given.

Case 1

The first situation dealt with passing a piece of work from one student to another within a group as illustrated in Figure 14.

> Students: *Pass your paper* to the person on your right. Write one answer for number (3) for the paper you just received. Your answer must begin with the first sound in the person's name (e.g. Mary - made a mess). Then *pass the paper again* and write an answer for (4), again using the same sound that begins the name. Continue doing this until all the blanks on all the papers are full. You should have lots of different answers from all the people in your group when your paper comes back to you!

Figure 14. Passing on a learning object within a group among all group members

LD allows the creation of groups by defining roles, and learning objects can be created and placed in an environment. A person in a role can be notified as soon as a person in a role has completed some activity. However, the problem at hand is that it is not possible to let a learning object circulate among other learners within the same role as is the case here.

The solution developed for this case uses properties and sub-roles to show or set a property value as illustrated in figure 15. For a group of three learners, three role parts are created. In the first act each learner fills in a field and thereby setting an LD property. Once all learners have completed this activity, the next act becomes active. Now each learner sees the property value set by another learner to which the learner has to respond by filling in a form and thereby setting a new LD property. When all learners have completed this activity, act 3 becomes available. In this last act, the learner sees the property value of the remaining learner and responds to the information filled in by the previous learner.

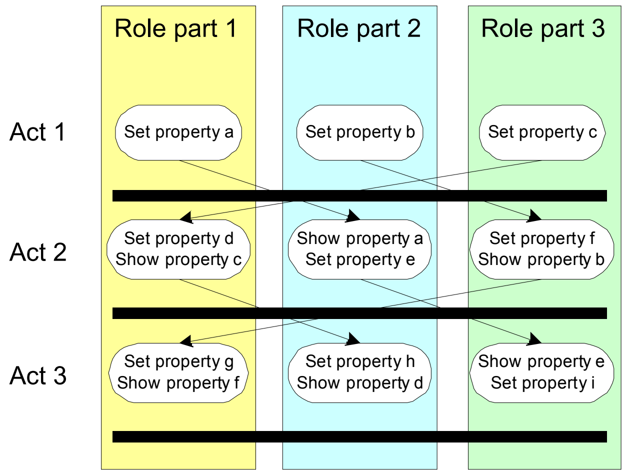


Figure 15. LD implementation for a circulating learning object

The solution provided works fine as long as the number of learners in a group are known beforehand, is fixed, and a group contains the required number of learners; the workflow must be adapted to the number of learners.

Case 2

The lesson plan where this situation occurred dealt with diving tables that divers need when they use compressed air to dive. See figure 16 for the text fragment of the lesson plan showing the problem. This type of situation could also occur in other situations where safety precautions must be followed, as in a construction task or a laboratory experiment.

> **Important Note**
> Diving can be a dangerous sport, which is why it's one of the few recreational activities that certifies participants. The Diving Table on page 8 is loosely based on dive tables used by the U.S. Navy without decompression stops and is included here for the purpose of introducing the basic concept of diving physiology. Its utility is limited to this purpose only. Potential divers must receive proper instruction by enrolling in a diver training program offered by recognized certification agencies.

Figure16. Warning information prior to a learning activity

LD has no specific method for representing this type of information, but there are other ways to reach a similar effect. The easiest way to warn learners of some danger is to include a warning message within an learning activity as instructional text or graphics. An alternative is making use of notifications. As soon as a learner starts a learning activity that needs a warning message, a property is set <*datetimeactivity-started*> which is compared with the date and time the activity was published. When the property value that was set is of a later time and/or date then the published date, a *notification* is send to the learner containing the warning or safety precautions.

Case 3

In two lesson plans, a situation occurred where a randomisation mechanism was needed. In one lesson plan students were required to pull a piece of paper from a bag (see figure 17), and the other plan used randomisation to provide a student from the group with a special task (see figure 18).

Have one student cut apart Activity Sheet 1 and place the slips of paper in the paper bag.

Figure 17. Warning information prior to a learning activity

A) Run a lottery to decide who will play the part of the disabled person, small pieces of paper are pulled from a bag and one is marked with a cross.
B) Ask the class to open their papers together. What are their feelings before they open the paper? After finding out whether it is them or not, how do they feel?

Figure 18. Random setting of personal property

In LD there is no in-built mechanism to provide randomisation. For the problem of selecting an assignment using LD, an activity selection could be created to set the number of activities when the selection is considered completed. That is, if the selection contains ten activities the learner may be required to complete only two before the whole selection is considered completed. One could also construct a web page (external service) to inform learners what to do. The learning activity then only contains a link to this web page.

Solving the problem of assigning one learner out of a group of learners with a special characteristic can also be done by LD but not randomly. On this occasion the characteristic did not involve performing different learning activities. Therefore a tutor could set a local-personal property <*locpers-property*> with one of the learners in a role. If a learner has to be assigned to a different role, a course administrator must assign this role to one of the learners and might use the same procedure as described in the lesson plan.

Case 4

On three occasions groups needed to be formed dynamically once a lesson was already started. One lesson plan made use of two types of groups, each containing their own learning activities. At a certain moment, new groups needed to be formed based on the old groups as shown in figure 19. In principle, this means that if there were initially two types of groups, A and B, new groups needed to be formed out of these groups with a mix of members from, both former groups. Another lesson plan instructed learners to form their own group (see figure 20), which is no problem in a class situation but not so straightforward using an e-learning platform. The third lesson plan instructed the teacher to divide the whole class into groups as shown in figure 21.

Figure 19. Forming new groups out of previous groups

Part A

Give students a few days to think about what they will include in the skit and with whom they will work. Let them choose their partners to write and enact a skit that summarizes life in the 1930's.

Group. Each combined group shares Fact Sheet information and prepares an oral presentation for the rest of the class.

Figure 20. Formation of groups by learners.

Divide your class into groups, and ask each group to create an aerial map of an area surrounding and including your school (without, of course, using any technology but their own imaginations).

Figure 21. Warning information prior to a learning activity

LD does not provide a mechanism for a learner to assign himself to a group. How learners are assigned to a role depends on the implementation of the runtime environment and the administrative system that is used.

Role population during delivery is very similar to the initial role population in the production stage. The main difference is the actor using this functionality. During the production stage, role population is considered to be an administrative task, dividing all assigned users of a run into either the staff or the learner role. The user does not require any knowledge of the LD itself.

During the delivery stage, the assignment of roles is further refined depending on the role definitions in the LD. The user who performs this task needs knowledge of the LD and also knowledge of the users. For the example in figure 20, the lesson plan states that students themselves should form new groups. Students can discuss with each other to determine with whom they want to work with and then individually assign themselves to a role. For the examples in figure 19 and 21 the teacher must be able assign learners to a sub-group. The runtime system needs to take care of these requirements in order to make these lesson plans work. The runtime system should also provide a mechanism to the user that allows switching of roles. Switching roles implies that the LD is viewed from a different perspective.

Case 5

Another teaching technique found in one of the lesson plans is often used in workshops and seminars, and provides an overview of existing knowledge, and what they want to learn during the session. Afterwards what students actually learned during the session is evaluated. In this lesson plan this technique was called a KWL chart, see figure 22.

Begin a class discussion by using a KWL chart [what the students know (K), what the students want to learn (W), and what they did learn (L)]. Elicit from the class what they already know about the depression, Roosevelt's New Deal, and the WPA.

Figure 22. Learner inventory form (KWL chart)

The illustrated problem can be approached in two ways. The first approach uses the conference service as defined in LD and the second approach uses properties and the monitor service of LD. Using the conference service makes it possible to assign different rights to the learnerssuch as participant, observer, moderator, or a conference-manager. One of the learners or the teacher can be assigned to the role of the moderator who collects the responses of the participants to the questions. This role is then asked to fill in the KWL chart and transfer the responses into LD local properties. Local properties are available to everyone who is subscribed to a run of a unit of learning using the show property value. The second approach uses global personal properties to enable every learner fill in a value of the KWL chart on their own. If a monitor service is created, the values entered by all learners can then be displayed to everyone.

Case 6

While many of the lesson plans investigated contained instructions for teachers on how to use the lesson plan, one lesson plan consisted almost entirely of instructions and suggestions for teachers.

> Introduction
> This unit was developed from the standpoint of a self-contained classroom where the same teacher would deliver the English, Reading and Social Studies instruction. The reading selections, activities and lessons are designed for fourth and fifth grade students, but can be adjusted to meet a variety of reading levels. There is no suggested timeline. This unit can be carried out in its entirety or dispersed throughout the year. It can be integrated with any literature program that is supported by student writing.
> ….
> The reason I chose memoir writing is because it deals with two difficult issues facing all writers (1) what to include and (2) what not to include. The author, Maya Angelou, once said, "This is a good 20 page paper, if I had had more time it would have been an excellent 10 page paper." In her book, How I Became a Writer, Phyllis Reynolds Naylor shares her view on the evolution of her work, "I've learned to let a manuscript sit for a few days or weeks, then read it again.
> …

Figure 23. Notes that serve as background information for the teacher who intends to use this lesson plan.

Currently there is no specific LD activity to covers this need, but there are two ways to achieve a similar result. In principle the information stated in figure 23 provides information about a lesson plan and is therefore meta-data. A meta-data specification that can be used for this purpose is IMS Meta-data for which a name space is provided in LD. In IMS Meta-data there is a tag called "description" in the branch of "education" which is may be used to provide comments on the conditions and use of the resource (learning activity in LD). There is however a limitation of 1000 characters for this field. Another way to provide information to a teacher on how to use a lesson plan is to make use of support activities. Although this type of activity is intended to provide activities to support learners, one can also interpret the instructions of the lesson plan creator as support for the teacher who is teaching the course. Support activities containing such teacher instructions can be coupled to a staff role so that only the teacher has access.

Summary

In this test to express a set of lesson plans in LD, we found six distinct cases requiring extra attention. The first case described a mechanism for a collaborative assignment that used a document circulated among the members of a group of learners. The second case described how a message can be shown before an activity is started; in this case, a safety warning. The third case described the use of a randomisation mechanism that was needed to select one member of a group. The fourth case identified the need that groups of learners have to be created at runtime. The fifth case described how the pre-knowledge, learning objectives and achieved learning objectives for a group of learners can be captured of each individual learner and exposed to the whole group of learners. The sixth case described the need to capture instructions from the lesson designer or a fellow teacher on how to use a lesson.

Conclusions

In this evaluation we have taken several lesson plans and investigated how well these plans could be expressed in LD. Although several lesson plans needed a work around, the main educational processes could all be described sufficiently with LD. On all but one occasion the work-around did not influence the overall learning process itself, but a small element of it. Only the workaround described in case 1 affected the main learning process. LD offers services that proved to be useful, such as mail, conference and a monitor. However, specific learning situations might require special services which are currently not offered in LD. For this, LD provides a mechanism to include services developed elsewhere. For example Hernández, Asensio Pérez, & Dimitriadis (2004) have developed a service specifically for computer supported collaborative learning (CSCL). We identified the need for two kinds of services in this test. The first one for a circulation mechanism of a learning object within a group where each member can edit a part of the learning object, and the second one is a randomly selected group member who can be assigned to a different role. Also a need exists to form new groups at runtime based on the outcomes of the learning process. The formation of groups at runtime is something which is foreseen in LD but is dependent on the implementation of the runtime environment. Future investigations could also specifically search for the identified problems in a larger number of lesson plans to gain an insight into the scale at which the problems occur.

We used three methods to test the expressiveness of LD because we also wanted to gather information on the effectiveness and efficiency of each method. Of the methods used, the expert analysis was the most efficient. The time spent by the two experts was less than time spent on the document analysis and LD coding. We also experienced that the expert analysis must be conducted with great care. It is necessary that the experts receive training prior to their rating activities so they interpret and rate situations in the same way. The reliability of the results is expected to increase as more experts rate the lesson plans, but this will be at the cost of time efficiency. It was not difficult to find experienced LD coders, but it was difficult to find LD coders that had sufficiently broad experience. The document analysis proved to be more effective and the results more reliable than those of the expert analysis. We draw this conclusion because coding the lesson plans identified no additional work-arounds to those already identified in the document analysis. However, this method is less efficient since it takes about a three times as much time as the expert analysis with two experts. In this test we only used one person to carry out the document analysis. Those carrying out the document analysis need to have the same qualifications as the experts previously mentioned. Finally the LD coding is the most time consuming method. It takes about ten times the amount of time spent on the document analysis to code a lesson plan in LD. This time could be shortened when specific LD editors become available; for this test we used a generic XML editor.

Future tests can make use of this test by further elaborating the methods used and refining the measurements. Document analysis would be the preferred method because it provides a good balance between efficiency and effectiveness. Quantitative measures require the analysis of many more lesson plans than analysed in this test. To achieve this, the use of tools for automated evaluation of text would be very useful. This would also enable testing to determine if the pedagogical flexibility requirement is met by LD as the results of this investigation were not conclusive enough.

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