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Modelling routes towards learning goals

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Abstract

Purpose – This paper aims to define the need for a route modelling language in e-learning, identifying requirements and candidate languages, before providing a recommended approach.

Design/methodology/approach – Several sources of requirements are drawn from the literature then used to review available approaches to route modelling. The best candidate is then applied in a number of case studies to check its applicability.

Findings – An existing open standard, IMS learning design, is identified as meeting the requirements. To date the standard has been applied in a different area, so the match to the route modelling problem is favorable.

Research limitations/implications – The scope of the work excluded an examination of requirements arising in the lifecycle management of routes; further investigation should check this point.

Practical implications – Practical application is hampered by the lack of an appropriate e-learning infrastructure in which to apply the approach. Pilot infrastructures should become available in the next 18 months to two years.

Originality/value – The work puts an existing e-learning specification in a new light, avoiding the need to develop a new language. Since tools and experience with the specification are already available, prospects for its adoption in a new role are favorable.

Keywords Curriculum development, Standards, E-learning, Lifelong learning, Objectives

Introduction

The use of the internet as a delivery technology for education and training is now commonplace, with both distance and presential learning providers exploiting e-learning in their offerings. A standards-based IT infrastructure is in place in educational institutions around the world, simplifying the delivery equation and opening the doors to mainstream, large-scale, web-based education (Brusilovsky and Vassileva, 2003).

In parallel with this major change in the delivery of education, and informed by constructivist educational theories, the nature of curriculum is undergoing reassessment. Rather than a fixed sequence of study, pre-determined by the teacher, these theories view curriculum as a process of co-development between teacher and learner (Granger, 1993; Kirkpatrick, 2001; Phelps *et al.*, 2005; Van den Berg *et al.*, 2004). Curriculum becomes a spectrum, extending from highly constrained situations in which all is fixed, through situations in which some room for manoeuvre is offered to

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learners to open unconstrained contexts in which sequence "emerges in the interaction between the learner and the environment" (Akhras and Self, 2002).

The article focuses on the formal and non-formal educational settings found in higher and adult education (Colley *et al.*, 2003; Livingstone, 2001). Here, a pre-determined curriculum is present, typically with various degrees of freedom for the learner to influence the selection and ordering of his or her learning experiences. Credit and modularisation play a central role in achieving this freedom (Brown and Saunders, 1995; Hart and Howieson, 2004; Moon, 1988) – modular educational systems revolve around units which can be combined (i.e. sequenced) by learners to reach educational goals.

Although offering advantages for curriculum flexibility, modularisation can also lead to complexity for learners. Yorke (2002) highlighted that "as the unitization of curricula spreads through higher education, so there is a need for greater guidance for students to navigate their way through the schemes", a point also noted by Gledhill (1999). Recent EU policy documents have stressed the importance of guidance systems (CEC, 2004a) and the need to help learners understand which educational choices are available to them and to provide support in the decision making process. At the "constrained" end of the curriculum spectrum, guidance systems can provide assistance to the learner by indicating how much of the pre-determined curriculum has been completed and how much remains to be done. At the "unconstrained" end, assistance can be offered through new technologies from the social software world (Dron, 2006; Janssen *et al.*, 2006; Okada and Zeiliger, 2003; Semet *et al.*, 2003; Wexelblat, 1999).

The large scale adoption of guidance systems is, however, handicapped by the absence of a standardised approach to describing curricula. The PLOTEUS initiative (PLOTEUS, 2006), for example, while laudable in its aims to help citizens find out information about studying in Europe, presents learners with a bewildering assortment of learning opportunities, each leading the enquirer to the vagaries of providers' web sites and the informal descriptions of curricula. Magoulas *et al.* (2006) argue that models need to be developed "that will allow local, regional, national and international systems to work together to provide coherent access to e-learning resources". Similarly, the operation of guidance systems in an "open, flexible and complementary way across education, training, employment and community sectors" has been identified (CEDEFOP, 2005) as a key systems coordination feature for lifelong guidance systems. Our work addresses this issue of systems interoperability – if the various institutes reachable though PLOTEUS used a common route modelling language to describe their offerings, guidance could help learners navigating within and between the various learning opportunities.

Requirements for a route modelling language

Before turning to the requirements, we introduce four concepts central to our work:

(1) Goals are the competence levels which learners aim to attain. Although it is possible for learners to embark on an intellectual quest with no closely specified, fixed, or terminal point in mind (Brookfield, 1985), guidance issues are inherently linked to deliberate learning, i.e. learning which is intentional, with a definite, specific goal (Knapper and Cropley, 1991).

(2) There can be several different route*s* to the attainment of a goal; the goal of a bachelor's degree in Fine Art can be attained by following study programmes at hundreds of universities across the world.

(3) Routes specify requirements to be met to achieve a goal in terms of combinations of units of learning (UoLs), an abstract term used to refer to any delimited piece of education or training, such as a course, a module, a lesson, etc. A route modelling language describes combinations of UoLs.

(4) A learner's position is those UoLs which have already been, or can be considered to have been, completed. Processes of recognition of prior learning, or prior learning assessment (Breier, 2005; Starr-Glass, 2002), can lead to learners being exempted from some of the requirements associated with the attainment of a goal. In this way, we speak of a positioning process which maps the results of learners' prior learning onto a route, leading to his or her position along the route; with this in hand, it is possible to determine what remains to be done to reach the goal associated with the route.

Requirements for a route modelling language can be found in the curriculum design literature (Bell and Wade, 1993; Ertl, 2002; Glatthorn *et al.*, 2005; Van den Akker, 2003), lifelong learning policy documents (NOCN, 2004a; SCQF, 2003) and literature on credit accumulation and transfer (Adam, 2001; Gosling, 2001; Winter, 1994).

We summarise the requirements in the following points:

(1) *Modular composition:* Routes to goals must be able to be constructed from units.
   - Example: In order to reach competency level 3, modules 45a, 33d and 67t must be successfully completed.

(2) *Nested composition:* Routes must be able to be composed of other routes.
   - Example: The course can be divided into two phases: the propedeutic phase and the post-propedeutic phase. The propedeutic phase consists of the following modules.

(3) *Selection:* It must be possible to specify which elements of a route are mandatory and which are optional.
   - Example: students must complete module H101, and may select any two modules from H101, H103, H104 or H105.

(4) *Sequencing:* it must be possible to specify constraints on the order in which elements of a route are to be completed.
   - Example: Students must first complete module "L-A4 An introduction to linguistics", before being allowed to commence module "L-G5 Psycho-linguistics".

(5) *Completion:* The requirements for completion of an element of a route, and of the route itself, must be able to be specified.
   - Example: Each module carries a specific credit value. Students need to accumulate 60 credits from the optional modules in order to progress from the propedeutic to the post-propedeutic phase.

(6) *Conditional composition:* It must be possible to specify conditions under which elements of a route are to be included or excluded.

- Example: Applicants whose mother tongue is English are not required to complete module E101.
- Example: Students who have completed the introduction to Psychology are not required to complete the History of Psychology course.
- Example: Learners who do not elect to follow the statistics course are required to follow an additional introduction to algebra course in the elective phase.

Furthermore, drawing on the educational modelling approach used in (Koper, 2004; Koper and Manderveld, 2004), we add the following generic requirements for the language:

(1) *Formality:* the language must describe a route in a formal way, so that automatic processing is possible.

(2) *Interoperability:* The language must support interoperability of routes so that different support systems can share and exchange information.

The latter two requirements are particularly relevant to the context of lifelong learning, where individuals' learning process cover long stretches of time, including periods of suspension and resumption. Learners must be supported in picking up from where they left off, and in switching to different providers; a formal, interoperable, standardised approach promotes portability of route information (so that modules completed on a route offered by a particular provider can be interchanged with modules on a route offered by another provider), sustainability of route information (so that as new versions of routes appear, learners can be automatically mapped onto comparable positions on the new versions) and comparison of route information (so that guidance systems can offer advice on alternative routes to a goal).

Related work on route modelling

There are a number of existing approaches to specifying what needs to be done by learners to achieve educational goals. The European Credit Transfer and Accumulation System or ECTS (CEC, 2004b), is a systematic way of describing the student workload required to achieve the objectives of an educational programme (e.g. "students must accumulate a total of 60 ECTS credit points"). ECTS is, however, not a formal modelling language and does not provide a means of fully specifying routes (e.g. there are no constructs to describe sequences and selections using ECTS). The National Open College Network Credit and Qualification Framework's Technical Specification for Qualifications (NOCN, 2004b) does include the notion of Rules of Combination describing mandatory and optional units. However, as yet, no formal modelling language is used for the specification of the rules, limiting the opportunities for automated processing.

Significant research in curriculum modelling has been carried out over the years in the area of Intelligent Tutoring Systems (Baldoni *et al.*, 2002; Karagiannidis *et al.*, 2001; Murray, 1998; Stern and Park Woolff, 1998; Xu *et al.*, 2005). While this work has a formal basis which meets the generic educational modelling requirements described above, approaches to curriculum modelling in the ITS worlds have tended to involve the modelling of conceptual domain knowledge (what is related to what in the domain) and the modelling of knowledge pre-requisites (what must be learned before what) so that automatic planning processes can perform curriculum sequencing. We view this as a far deeper and correspondingly more taxing level of modelling than is required for guidance. Rather than modelling domains, a more pragmatic approach may be to model UoLs about the domains, and to use this information during guidance.

Finally, work on the eXchanging Course-Related Information (XCRI, 2006) reference model is drawing on a number of other international initiatives, particularly from the Scandinavian countries, to define a vocabulary for describing course-related information encompassing course marketing, course quality assurance, enrolment and reporting requirements. This is interesting work in progress, albeit with a scope which is slightly different to that of the work described in this article, focusing more on institutional publication of course information to diverse audiences rather than the learner guidance problem. However, the XCRI reference model includes some facilities for modelling routes which we believe could be usefully extended with the constructs included in this article.

IMS learning design as a route modelling language

Another candidate for a route modelling language is IMS Learning Design (IMSLD, 2003; Koper and Olivier, 2004; Koper and Tattersall, 2005). IMSLD provides constructs allowing instructional designers to specify which roles should carry out which activities, with which supportive learning materials and services in order to achieve learning objectives. The bulk of the literature on IMSLD has addressed its application to the modelling of the internal structure of UoLs at a micro level for subsequent "playing" in a virtual learning environment. However, the specification permits varying levels of granularity of a unit of learning, referring to "any delimited piece of education or training such as courses, modules or lessons"; a (macro) unit of learning can be defined in terms of other UoLs to describe routes towards goals. Using IMSLD in this way at the macro level does not require its full sophistication, simplifying the modelling task. Such use also targets a different kind of context of use: one which compares routes expressed in IMSLD with learner positions to determine what remains to be done to reach a goal.

Given its pedigree as an educational modelling language, IMSLD would seem a suitable candidate for a route modelling language. Table I illustrates how the requirements identified above are met using the constructs of IMSLD.

In order to illustrate the way in which IMSLD can be applied to route modelling, consider the following fictitious example route, associated with the goal of becoming a Bachelor of General Studies:

> The major block of the programme consists of a module on "Philosophy", followed by the choice of two modules from "Aesthetics", "Art", "Religious Studies" or "Music". Following the major block, two alternative minor programmes are available, students either elect to study, in any order, "Biology", "Physics" and "Chemistry", or elect to study first "History" then "Geography".

Figure 1 shows a diagrammatic representation of the programme. The outer, black block represents the study programme UoL which models the route. The white boxes representing the individual, module-level UoLs. Grey boxes show the various layers of nested activity structures dealing with sequences and selections.

The flexibility offered in this route means that once learners have mastered Philosophy, many different combinations of modules can be followed to complete the programme and attain the associated competence level (e.g. aesthetics, art, history then geography or religious studies, music, chemistry, biology then physics, etc).

Modular composition	A UoL can reference another UoL within an activity structure through a uniform resource identifier
Nested composition	Activity structures can be nested, thereby allowing nesting of UoLs
Selection	The type of an activity structure can be indicated as a selection indicating that the elements of the selection may be done in any order. Moreover an attribute can be specified (number-to-select) to indicate how many elements of the activity structure must be completed before the whole activity structure is considered complete (e.g. four of the six specified possibilities, one of the seven etc.)
Sequencing	The type of an activity structure can be indicated as a sequence indicating that the elements of the selection must be done in the specified order
Completion	IMSLD has an expression language through which complex rules for completion can be defined
Conditional composition	The expression language can also be used to describe conditions based on various types of properties (of the learner, the route, etc.)
Formality	IMSLD is described using the XML Schema formalism allowing various types of processing to be brought to bear on information modelled using the specification
Interoperability	IMSLD is an open specification published by a consortium which promotes e-learning interoperability

Table I. Matching IMS LD against the route modelling requirements

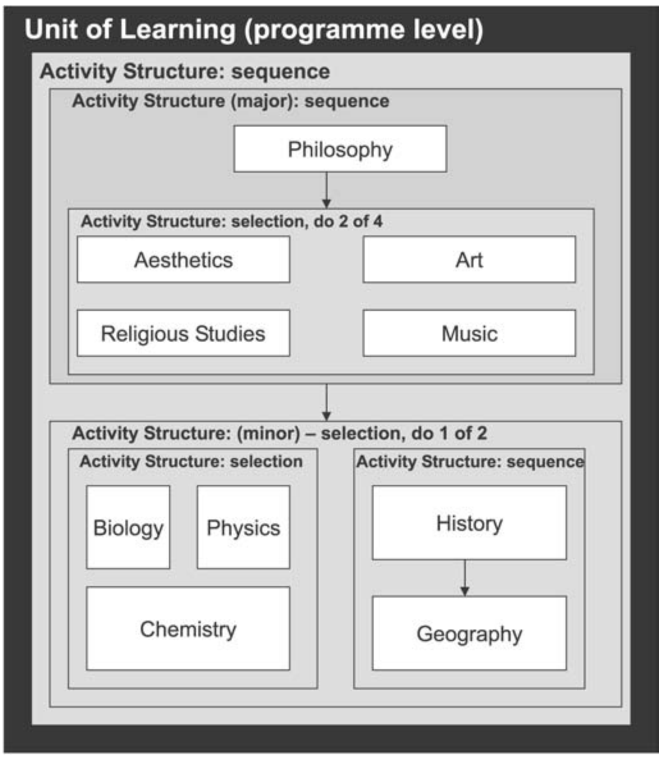

Figure 1. One route to becoming a Bachelor of general studies

Figure 2 shows an editor being used to create the formal IMSLD representation for the above situation.

Case studies

In order to investigate whether IMSLD is suitable for modelling learning routes, three sources of programmes were used. First, the distance teaching programmes offered at the Open University of the Netherlands were analysed. Second, an analysis was made of a selection of curricula found via the PLOTEUS service. Finally, a set of learning programmes which can be found on the internet was analysed.

A sample of the results of the analysis is shown below, whereby the description of the programme is matched with a textual description of its mapping to IMSLD (XML code is excluded for clarity):

(1) *Bachelor's degree programme in Dutch Law*:

- The Bachelor programme in Dutch Law consists of 42 modules and is divided into two phases: the propedeutic phase (14 modules) and the post-propedeutic phase (26 modules). The former begins with an introductory course in Law (which counts for two modules) after which students follow the remaining 12 modules in any order. The modules of the post-propedeutic phase can be followed in any order. The bachelor is completed with a compulsory "integration practical", which counts for two modules.
- The UoL representing this route consists of an IMSLD Activity Structure (AS) which is a sequence, containing nested AS's for both the propedeutic

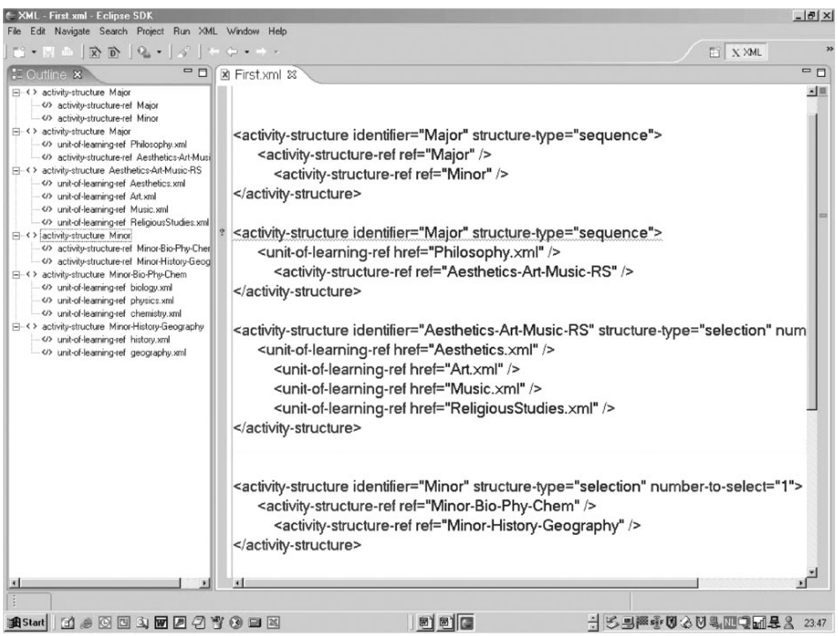

Figure 2.
Representing the programme using IMSLD

and post-propedeutic phases, followed by a UoL representing the practical. The propedeutic phase is a sequence which starts with the UoL for the introductory course and is followed by a nested AS representing the remaining 12 modules (a selection). The post-propedeutic phase AS is a selection of the 26 modules.

(2) *Master of science in psychological research*:
- The programme consists of four modules which can be followed in any order, followed by a block from which two courses must be chosen from a selection of named research courses.
- The master programme is modelled as an AS (sequence) of two other ASs. The first is a selection of four modules while the second is again a selection (number-to-select = 2) of the research courses.

(3) *European computer driving licence, e-citizen programme (ECDL, 2006)*:
- e-Citizen is the new end-user computer skills certification programme from the European Computer Driving Licence (ECDL) Foundation. The programme is designed to cater for those with a limited knowledge of computers and the internet but who wish to gain valuable everyday computer and internet skills. The e-citizen syllabus has been defined by the ECDL Foundation in three blocks which are followed in progression: Block 1: Foundation Skills, Block 2: Information Search and Block 3: E-Participation. Each block consists of a number of topics (e.g. the computer, files and folders).
- A UoL is defined for each topic and grouped into an AS per block (selection). These three ASs are included in a sequence AS, ordering the blocks in the correct sequence.

(4) *Driving goods vehicles national vocational qualification (NVQ, 2003)*:
- The Level 3 qualification is for drivers who can show broader driving competencies and be considered as professional goods vehicle drivers. Drivers must obtain all eight mandatory units, plus at least any two optional units from four specified for a full award.
- This programme again follows the pattern of two ASs, one dealing with mandatory modules (selection), the other dealing with elective modules (selection, number-to-select = 2)

(5) *University of Washington Certificate Program in Aircraft Composite Materials and Manufacturing (UoW, 2006)*:
- This online learning programme targets employed engineers and others who cannot take courses on campus. Coursework must be completed in order, beginning with aircraft composite materials, followed by aircraft composite manufacturing. Thereafter, learners choose one of two elective courses: aircraft composite tooling or aircraft composite repair.
- This certificate programme is modelled with an AS of type sequence, which orders the first two modules, followed by a nested AS of type selection (number-to-select = 1) containing UoLs representing the two elective modules.

(6) *UK national vocational qualification for registered manager (Edexcel, 2006)*:
- The qualification is intended for managers, assistant managers and others who have managerial responsibilities within regulated care services. All four mandatory units, one unit from each of the four optional groups and two units from any of the optional groups are required for successful completion of this NVQ.
- Although seemingly comparable with the examples described above, this route requires a higher degree of sophistication of IMSLD modelling. The mandatory units are dealt with using an AS of type selection. Learners' constrained picking and mixing from the four optional groups is handled using conditions. An AS containing all 16 optional modules is defined, together with a number of conditions. The conditions track whether one UoL from each group has been completed and whether two additional UoLs have been completed. Figure 3 shows one of the conditions being edited.

(7) *BA in computer science – systems and applications computer science (OUI, 2006)*:
- Students must accumulate 29 credits from the required modules and 14 credits from the elective modules. Those who have already taken formal automata theory may not take automata theory and formal languages and must therefore accumulate 31 credits from required courses and 12 credits in electives in computer science.
- The heart of this route is straightforward to model using activity structures. IMSLD conditions are, however, required first to track the ongoing accumulation of credit points (since course completion depends on a credit total rather than on a number of completed modules), as well as to adjust the total needed from the required modules depending on information on the learner's course history, excluding the relevant course (in IMSLD terms, using HIDE) appropriately.

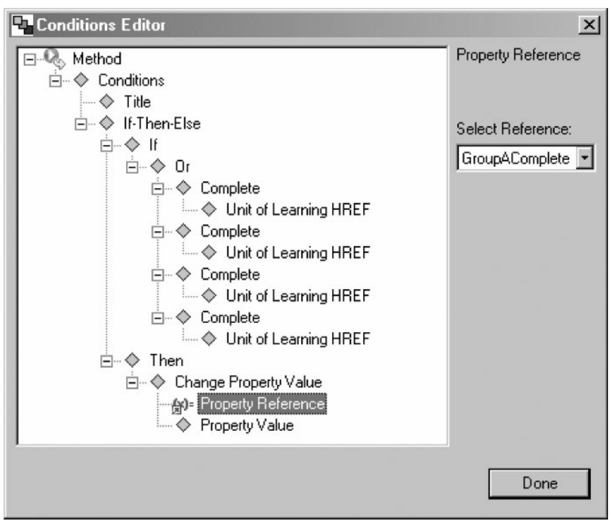

Figure 3.
Setting up IMSLD conditions

The seven case studies cover the various route-modelling requirements listed earlier in the paper.

Discussion

IMSLD's ability to sequence, select and nest various combinations of units of learning, together with its condition language provide a suitable base from which to tackle a variety of route modelling issues. Although many approaches, languages and formalisms exist in which routes could be specified (e.g. word processing documents, Java programs, HTML), IMSLD's nature as an open specification, published by non-profit organisation committed to its maintenance and with a growing set of development tools, make it an attractive solution to the route modelling problem; using it avoids the need to develop a new route modelling language to underpin learner guidance support systems.

Clearly, adopting IMSLD as a route modelling language requires other pieces of the e-learning interoperability jigsaw being in place for the approach to work:

- e-learning modules which are addressable as UoLs and able to be referenced from "route UoLs" (which can in turn be referenced from other UoLs).
- learner record systems, or e-portfolios, so that conditions can be defined in terms of their content;
- infrastructure to record in the above systems that a UoL has been completed, propagating this fact to associated systems;
- agreed naming conventions for competences, again so that conditions can be created; and
- a route processing engine, which, given a route modelled using IMSLD and the results of a learner positioning process, is able to compute what remains to be done by the learner to reach his or her educational goal.

Further analysis is needed on the implications of route lifecycle management to confirm that IMSLD's expression language offers all the constructs needed to deal with versioning, splitting and merging of UoLs over time. In addition, a separate research strand is needed on visualising routes, positions and "to do lists" for learners, particularly in cases of complex nesting of activity structures and high degrees of optionality. Moreover, additional analysis is needed to confirm IMSLD's role in modelling "emergent routes" (the work of Rasseneur *et al.* (2004) would seem to confirm this assumption).

The next step is to apply the approach in pilot learning situations built upon the appropriate infrastructure (e-portfolios, positioning services etc.) to gain additional feedback on its applicability. The results of this evaluation will be reported in subsequent articles.

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