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Abstract

The traditional notion of the curriculum as a fixed list of topics to be studied sequentially is under strain as pressure for flexibility in education increases. However, curriculum flexibility can lead to curriculum complexity, hindering learners in the development of their competences. This article presents a formal model for the description of curricula, designed to underpin guidance support systems for learners. The article compares the model to other work in the area, illustrates its application with a number of case studies and concludes with a discussion of the broader e-learning infrastructure required in implementing the approach.

1. Introduction

A standards-based IT infrastructure is now in place in educational institutions around the world, simplifying the delivery equation and opening the doors to mainstream, large-scale, web-based education [1] and offering the possibility of increased curriculum flexibility [2]. Traditionally, educational systems have shown a rigid character, with learners being grouped into cohorts for fixed-length programmes with pre-determined start dates and pre-determined structures [3]. In contrast, flexible systems are designed to allow learners "to follow open learning pathways of their own choice, rather than being obliged to follow predetermined routes to specific destinations" [4].
Credit and modularisation play a central role in achieving this freedom [5]; modular educational systems revolve around units which can be combined (i.e. sequenced) by learners to reach educational goals. However, the flipside of modularisation is complexity. Yorke [6] highlights 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". This point is also raised by Gledhill [7] who notes the complexity inherent in modular programmes and the difficulties this implies for advice-giving.
These difficulties can be seen at the website of the PLOTEUS initiative [8] which aims to help students, job seekers, workers, parents, guidance counsellors and teachers find out information about studying in Europe. Although extensive in its coverage, the portal presents learners with a bewildering assortment of learning opportunities, each leading the enquirer to the vagaries of providers' websites. In the absence of a standardised approach to describing the curricula related to the opportunities, learner guidance in the form of directions for progression is costly and piecemeal. This articles starting point is that a standardised language for modelling curricula would ease the development of automated guidance systems in e-learning.

2. Curriculum Modelling Requirements

Requirements for the modelling of curricula can be found in the curriculum design literature [9-12], lifelong learning policy documents [13, 14] and literature on credit accumulation and transfer [15-17]. We summarise the requirements in the following points:

- *Modular composition*: Curricula 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.
- *Nested composition*: Curricula must be able to be composed of other curricula. Example: the Course can be divided into two phases: the propedeutic phase and the post-propedeutic phase. The former consists of the following modules …
- *Selection*: It must be possible to specify which elements of a curriculum are mandatory and which

are optional. Example: Students must complete module H101, and may select any two modules from H101, H103, H104 or H105
- *Sequencing*: it must be possible to specify constraints on the order in which elements of a curriculum 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”
- *Completion*: The requirements for completion of a curriculum element, and of the curriculum 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.
- *Conditional Composition*: It must be possible to specify conditions under which curriculum elements 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 [18], we add the following generic requirements:

- *Formality*: the language must describe a curriculum in a formal way, so that automatic processing is possible.
- *Interoperability*: The language must support interoperability of curricula so that different support systems can share and exchange information.

3. Related Work

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 [19], 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 curricula (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 [20] 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 [21, 22]. 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 [23] 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 curricula which we believe could be usefully extended with the constructs included in this article.

4. IMS Learning Design as a Curriculum Modelling Language

Another candidate for a curriculum modelling language is IMS Learning Design [24, 25]. 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 curricula. Using IMSLD in this way at the macro level does not require its full sophistication, simplifying the modelling task.
Given its pedigree as an educational modelling language, IMSLD would seem a suitable candidate for a curriculum modelling language. Table 1 illustrates how the requirements identified above are met using the constructs of IMSLD.

Modular composition	A UoL can reference another UoL within an activity structure through a uniform resource identifier. We note here for completeness that the text of the IMSLD specification contains a technical restriction in the area of inter-UoL referencing but which is not formally enforced in the associated XML schema.
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 curriculum, 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 1. Matching IMS LD against the curriculum modelling requirements

5. Case Studies

In order to investigate whether IMSLD is suitable for modelling curricula, 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).

- Bachelors 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 2 modules.
    - The UoL representing this curriculum consists of an IMSLD Activity Structure (AS) which is a sequence, containing nested ASs for both the propedeutic 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.

- European Computer Driving Licence, e-citizen programme [26]
  - 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.
- Driving Goods Vehicles National Vocational Qualification [27]
  - 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 8 mandatory units, plus at least any 2 optional units from 4 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)
- University of Washington Certificate Program in Aircraft Composite Materials and Manufacturing [28].
  - 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
- UK National Vocational Qualification for Registered Manager [29]
  - 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 curriculum 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 2 additional UoLs have been completed.
- B.A. in Computer Science - Systems & 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 curriculum 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.

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

6. 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 curriculum modelling issues.

Although many approaches, languages and formalisms exist in which curricula could be specified (e.g. word processing documents, Java programs, HTML), IMSLD's nature as an open specification, published by a non-profit organisation committed to its maintenance and with a growing set of development tools, make it an attractive solution to the curriculum modelling problem; using it avoids the need to develop a new language to underpin learner guidance support systems.

Clearly, adopting IMSLD as a curriculum 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 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
- A curriculum processing engine, which, given a curriculum modelled using IMSLD and information on the learner, 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 curriculum 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 curricula, particularly in cases of complex nesting of activity structures and high degrees of optionality. Such additional work is needed to support both the appropriation of curricula described by Rasseneur et al. [30] and the usage analysis described by Barré et al. [31].

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.

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