An ontology-based curriculum knowledgebase for managing complexity and change

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Abstract

A curriculum knowledgebase, based on a visual model and ontology, is presented part way through its development lifecycle. The early modelling stages have yielded a means to tackle the complex curriculum structure, an operational knowledgebase and consensus among the domain experts on the ways in which the academic curriculum development team, students and administrators will interact with the curriculum and become involved with its ongoing maintenance and enhancement. Development continues of route-based and collaborative editing interfaces to the knowledgebase. The knowledgebase system is generally applicable to all structured curricula and is being evaluated in three schools of medicine that use Problem Based Learning.

1. Introduction

In order to be responsive to change in the outside world and to learner needs, a curriculum must be continually tended. A means is needed by which the academic curriculum development team, tutors, administrators and students may all become involved in the maintenance and enhancement of a complex structured curriculum. This paper describes the development of a knowledgebase system which addresses the complexity of the interrelationships between the component parts of undergraduate enquiry based learning in medicine and other structured curricula such as Dentistry and Engineering and provides an approach to their collaborative maintenance. A search for available tools to tackle these matters did not yield any that could support the design, development and maintenance of such curricula in a coherent manner, nor in any kind of teamwork environment. One curriculum database was identified, available only to the US and Canada, but apart from its availability issue, it does not address the collaboration aspect and its linkages between elements are limited [1]. The CRAMPON system, described here, is still under development but there are already interesting outcomes to report from early iterations with the domain experts. The work is being carried out in the context of a JISC [2] funded project. All the outputs of this work will be made available on the project website [3]. This paper will focus on the underpinning model for the system and the principles on which the user interfaces are designed. This model can serve as the basis for others to develop curriculum supporting systems.

The knowledgebase system is required to manage and maintain the complex interrelationships between curriculum content, cases for enquiry based learning and their intended learning outcomes (ILOs), and assessment blueprinting based on the ILOs. The system is generic for any structured curriculum but is being tested on the Manchester MBChB curriculum, using Index Clinical Situations, Module ILOs, Formative and Summative Assessment and Problem Based Learning (PBL) cases [4].

Figure 1 Curriculum Maintenance System

The principal users of the system, illustrated in Figure 1, will be tutors in the academic curriculum development teams and students who will use appropriate search facilities to plan their learning. In addition, administrators will use the system for planning programme delivery.
2. The Problem of Complexity and Change

The project test case is the curriculum for undergraduate medical students at the Manchester Medical School which is centred on a Problem Based Learning (PBL) approach to learning. The curriculum consists of a number of themed modules each having its own ILOs and set of clinical skills. The students gain their required knowledge and skills through study and analysis of a set of themed PBL cases derived from a core curriculum of Index Clinical Situations (ICS). Student learning is augmented by lectures, seminars and clinical placements and skills training. Each student is assessed throughout the five year programme, using a range of assessment techniques, to ensure they have acquired the relevant skills and knowledge and have achieved the standard required by the General Medical Council (GMC) [5] to be fit to practice.

The curriculum based on the ICSs, themed modules and ILOs, assessments and standards form a complex, multi-dimensional matrix of information elements which are linked through many-to-many relationships at multiple levels of granularity. This complexity presents problems on two fronts: for academics in preparation for quality reviews, and planning and executing changes to the curriculum; and for students making appropriate aspects of the curriculum intuitively visible to facilitate self-direction of their own learning. For example, updating any aspect of the curriculum in line with new guidelines from the Quality Assurance Agency for Higher Education (QAA) [6] or the GMC, involves identifying and tracking all the related parts on which that aspect may impinge and agreeing the changes within the curriculum development team.

There are known difficulties in the transition from traditional instruction to a PBL approach [7,8] and curriculum design must address issues of preparing a syllabus, finding appropriate problems/cases to address content, introducing students to group process and learning skills, etc. In addition, the curricula of degrees related to professional qualifications like Medicine have to undergo a continual process of review; either for purposes of development, modernization or review by a professional body, e.g. by the GMC. Reviews are complex and have to be completed in relatively short time-frames.

The medical curriculum must remain dynamic and respond to changes in medical practice and legislation but its maintenance is becoming increasingly difficult and expensive.

3. The Development Approach

The elements of the system comprise an underpinning formal visual model, an ontology and a knowledgebase containing all the necessary elements and their inter-connections. The knowledgebase has intuitive interfaces suited to the patterns of use of academic and clinical tutors, students and administrators. One of the user interfaces is embedded in a social software framework allowing teams to work together on curriculum documents in a collaborative editing environment. It is envisaged that the user interface will enable students, either as individuals or groups, to plan their learning. If their self-directed learning is supported by an e-portfolio, the students will be able to link between the curriculum knowledgebase and their own portfolios.

An iterative development method was employed with early involvement of the domain experts. These were the directors of the Undergraduate Medical Programme, director of Curriculum Development and Student Support and the Academic Lead for Assessment. The first stage of the process was to build and review a visual model of ‘Curriculum World’ which would allow the domain experts to establish that all the elements needed were included and to describe the connections and interactions between them. Administrators and students will be involved in the later iterations and their contributions will be reported in a future paper.

The visual model, a small part of which is shown in Figure 2, was built as a UML Class Diagram [9] and refined in discussion with the domain experts.

![Figure 2 Visual Model](image)

As illustrated in Figure 2, it emerged from these discussions that the core concept for this curriculum is the Intended Learning Outcome (ILO) which is an articulation of Competency. Competencies are complex mixtures of knowledge, skills and behaviour (personal qualities). An individual student’s competencies are initially acquired at a relatively low
level of expertise and honed as more experience is gained. The student spirals up through the curriculum acquiring and refining competencies.

Maintenance of the curriculum thus depends on ensuring coverage of the competencies in the PBL cases and their underlying ICSs alongside the lectures, seminars and clinical learning activities in the workplace. Acquisition of knowledge and expertise takes place in a wide range of learning activities, both theoretical and practical. The curriculum team aim to provide the PBL and other learning opportunities in a manner that maximises the student’s potential to build his knowledge and expertise.

The model allows the competencies to be considered as being situated in a multi-dimensional space. The co-ordinates of any one competency may be captured by ‘tagging’ it with values from (a) Programme Aims (b) Programme Strand (c) System Level (d) Outcome and (e) GMC requirements specification. It should also be clear that these tags could be modified for any curriculum in any institution, allowing the positioning of competencies in any number of dimensions according to the principal tenets of the curriculum. This space may then be reviewed for ‘gaps’ and ‘overcrowding’. Previous work on curriculum maintenance has been very much hampered by this multidimensionality since it is extremely difficult to hold such complex interrelationships in a way that facilitates review and planning without technology support.

Moving from this visual model to a knowledgebase populated with the curriculum content was achieved by building the model as an ontology in OWL [10] and providing a knowledgebase explorer, a database and a document management facility. This technology was already in place and undergoing trials in a related project for contextualising the JISC e-Framework [11], Innovation Base [12]. The technology will be provided as Open Source on completion.

4. User Views of the Knowledgebase

For curriculum maintenance, an appropriate interface is required to tackle the complex interdependencies between the elements. The visual metaphor for this is the London Underground map [13], familiar to all the system’s users. On this map there are stations and links between them. Not all stations are linked to all others but there are generally a number of routes that may be taken between stations. The elements in the ontology provide the stations, their object properties (relationships) the lines between stations. Once the user has picked a route, the knowledgebase contents become available for those stations. The user may select a particular instance from the list at his first station and the linked set become available at the next. In this way the user may follow trails of related items.

A second interface will be made available for collaborative editing of any of the curriculum documents such as PBL cases or ICSs. The user will be a member of a curriculum development team which will be managed in a social networking tool, e-laborate [14] also a parallel development to this system and soon to become generally available. The curriculum team will review a particular document and will receive all the linked elements as supporting documents for that work. Alternatively, a search may be made across the knowledgebase on the basis of a topic or term within the focus document and all the returned elements viewed. For any of these the user may choose to (a) link it to the focus document (b) un-link it from the focus document or (c) amend it.

Through these two very different user interfaces the system provides a repository for the curriculum which allows subsequent manipulation and configuration management.

5. Capabilities of the System

The curriculum knowledgebase, on completion, will allow a range of curriculum design, development and maintenance operations, as described in Table 1:

<table>
<thead>
<tr>
<th>Table 1 Capabilities of the Knowledgebase System</th>
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<tbody>
<tr>
<td>Support definition of a core curriculum that may be used to separate foundation material from later, more advanced or complex concepts</td>
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<tr>
<td>Support mapping of external criteria onto the curriculum to ensure the programme is meeting performance quality criteria</td>
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<tr>
<td>Link assessments to the curriculum as a form of blueprinting to ensure that the curriculum is examined appropriately and systematically</td>
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<td>Ensure that the curriculum is actually being delivered through the PBL cases in the themed semesters</td>
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<tr>
<td>Allow curriculum content design and revision to be more systematic, rigorous and transparent, while simultaneously extending ‘ownership’ of the curriculum to a larger group of teachers who would otherwise never be consulted</td>
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<tr>
<td>Manage the process of change in any of the curriculum components and its impact on the curriculum overall</td>
</tr>
<tr>
<td>Allow focus on management of the curriculum in any professional qualification (for example, engineering, medicine, dentistry)</td>
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138
Allow students’ planning of their learning to be better structured. For example, allowing identification of strands of activity in the programme for scaffolding learning.

Provide connection to an e-portfolio that will allow learners to maintain learning logs in a far more systematic manner, enabling the construction of more focused action plans to remedy weaknesses in learning and skills.

Allow browsing of the curriculum according to routes tailored to a set of student, tutor and administrator required viewpoints.

Allow search for particular elements of the curriculum by both students and curriculum designers. The ability to search the knowledgebase could, to some extent, alleviate the well known problems of uncertainty and anxiety among students in PBL programmes.

Support widespread collaboration and consultation on curriculum expertise inside and outside the institution by embedding in social software.

6. Early evaluation of the approach

The approach to development requires that we implement the knowledgebase and capture user evaluations over a number of iterations. Early in development, workshops were held in the two medical schools outside Manchester (Keele and Plymouth) that will be piloting the system. These aimed to establish whether the visual model and the ontology fitted their curricula and the ways in which they plan to maintain them. In these workshops the overview of the system as shown in Figure 3 was used to discuss potential uses of the system and two scenario building activities were tried in order to validate the visual model and ontology: (a) using ontology element cards to create scenarios and (b) marking elements required for a scenario in a spreadsheet of the ontology elements and their relationships. In addition, there were activities designed to establish the usefulness of tagging the elements in order to position them in the complex curriculum space.

The ontology cards seemed to be more successful than the spreadsheet representation of the model for getting people engaged in considering the tasks in which they could benefit from a knowledgebase system and in selecting the knowledge elements required to support those tasks. This activity required the participants to work in small groups to do the following:

- Choose a curriculum-related task and write its name on the task card;
- Imagine the activities involved in carrying out that task and the people and things that would be involved;
- Collect the element cards (cards were provided for all the ontology elements, each with a definition and an icon) that you think will play a part in that task;
- Write on the cards brief notes relating to the concrete example that was chosen;
- Consider the connections (relationships) between the elements;
- Stick the cards to the sheet and draw the relationships between them, remembering to give the lines meaningful names.

The academic and management staff who participated in these workshops were all capable of carrying out this ‘modelling’ activity and constructed their models in a short time (approximately 30 minutes).

The element tagging activities had mixed results since the participants chose to tag many of the elements with many of the tags. This led to an exercise in refinement of the tags and the decision to position only competencies, all other elements’ positions being derived by their relationships to the competencies.

The overall result of these workshops was confirmation of the core elements set in the ontology and general agreement around the types of task that the
system should be able to support. The workshops also confirmed the central position of ‘competencies’, articulated as ILOs, in managing and maintaining the curriculum. Further workshops are planned for testing out the route-based and collaborative editing interfaces to the knowledgebase populated with sample data.

7. Summary and Next Steps

The knowledgebase system has taken an integrated holistic approach to curriculum design and maintenance, addressing the needs of student, tutor and administrator. It uses domain modelling and knowledge engineering to tackle the complex interrelationships of the composite elements of a structured curriculum. In addition it tackles the need to support collaboration in curriculum maintenance by embedding the knowledgebase application within social software. The underpinning architecture of the knowledgebase system assures extensibility for multiple knowledgebases and multiple user interfaces.

The creation of an operational curriculum knowledgebase allows a range of institutional stakeholders to use technology in the planning, delivery and enhancement of the educational experience. The availability of an easily-interrogated knowledgebase that links all the elements of a complex curriculum will allow teachers to plan and deliver a more precise and appropriate learning experience. At the same time, the knowledgebase application will allow students to plan and manage a personal, high quality learning experience by mapping and tracking curriculum progress to individual learning objectives and skills.

The knowledgebase supports the personalisation of the learning experience by enabling student progression to be student led, as opposed to curriculum based. A programme designed for enquiry based learning utilising PBL provides the opportunity for a flexible, personalised approach to learning; yet this is only possible if the student is able to match cases to the full set of skills and knowledge required. Students need to be confident that they are achieving curriculum coverage with their self-directed learning. This system will grant students this facility, and provide the mapping to relevant assessments and their own evidence record of progress and achievement.

The knowledgebase application provides a key element of a flexible technical infrastructure which is based on community involvement and collaboration. It will also enable a more cost effective and flexible approach to curriculum administration, maintenance and improvement through rapid and efficient identification of relevant curriculum elements and support of collaborative work on the curriculum. The next steps in its development include the two distinct user interfaces, route based and document focused. The curriculum knowledgebase system will be evaluated within the three participating medical schools.

10. References

[3] The CRAMPON project, University of Manchester http://www.medicine.manchester.ac.uk/crampon/
[10] W3C OWL Web Ontology Language http://www.w3.org/TR/owl-features/
[12] JISC InnovationBase http://www.ib.ecs.soton.ac.uk/