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REUSE THROUGH RAPID DEVELOPMENT

Eamon Costello

Oscail, Dublin City University, Ireland
E-mail: eamon.costello@dcu.ie

ABSTRACT
The general issue of reuse of digital resources, called Learning Objects (LOs), in education is discussed here. Ideas are drawn from software engineering which has long grappled with the reuse problem. Arguments are presented for rapid development methodologies and a corresponding method for generation of online mathematics question banks is described.

INTRODUCTION
Oscail, National Distance Education Centre in Dublin City University provides a BSc in Information Technology by distance. Increasing use is made of Internet technologies in the delivery of this programme. Here we will focus on the use of digital resources known as Learning Objects (LOs), using online assessment questions as an example. The potential reusability of LOs is examined, as a concept that appears in the research fields of both software engineering and educational technology. Finally the method of generation of online question banks is posited as a factor of reusability.

THE PROMISE OF REUSE
The IEEE defines a Learning Object (LO) as "any entity, digital or non-digital, that may be used for learning, education or training". The 'Object' of the term LO has its etymology in computer science, where it means something precise with well defined properties. To generalise however we can say that one of the engineering cornerstones of object technology is the concept of reusability [1]. The business case for objects is that reusing components alleviates costly development. The idea of reusability is very apparent in LO research where the terms *Reusable* Learning Object (RLO) and *Shareable* Content Object (SCO) are widely used [2][3].

THE PROBLEM OF REUSE
Reuse is difficult to achieve in practice. Education researchers claim that "use" can be more accurately described as "contextualization" which refers to the process of designer (or automated system) placing an LO into an instructional context [4]. Obviously a small, self-contained LO is at home in more contexts than a large complex one. By this reasoning an LO's granularity is proportional to its reusability. However, though a small granular LO may itself fit into many contexts, there arises the effort of selecting and combining many small LOs in a meaningful way.

Standards such as the Sharable Content Objects Reference Model (SCORM) attempt to address reuse in a systematic way by providing standards to enable plug-and-play LOs [5]. LOs in SCORM are pieces of digital content which are served from a web-based learning system. LOs (in SCORM parlance SCOs) communicate with the

system, and indirectly with each other, through a defined API at runtime. Meta-data specifications allow for description of the LOs and even LO subcomponents (known as assets). These specifications are now known as IEEE LOM (Learning Object Meta-data). XML bindings for this meta-data are available from the IMS Global Learning Consortium. Collections of SCOs, such as into hierarchical aggregations (e.g. into units, modules courses), are defined with further XML bindings known as *packaging application profiles* for SCORM. The latest SCORM developments allow for definitions of dynamic sequencing of content. The IEEE is now an active participant in these standards.

Another standard - Question Test and Interoperability (QTI) from IMS Global Learning Consortium - focuses specifically on online questions and tests. It is slightly smaller than the SCORM but both standards are complex and ultimately to some, unwieldy [6]. Contributing to this complexity is the layers of meta-data that must be wrapped around educational resources to transform them into loosely-coupled reusable objects. Although SCORM et al have gained popularity they appear to exhibit some characteristics of standards, such as the OSI Reference Model, whose sheer size and detail begins to impinge on practical application [7].

NEW THINKING ON REUSE

In recent years some of the claims made for reuse in software engineering have been questioned [8]. One problem is that the context where software will be reused cannot be reliably predicted. Much code is actually rewritten rather than reused through the mechanisms provided for by object-orientated principles. Taking code apart and *refactoring* it in this way is part of the field of Agile Methodologies. On one level it represents a pragmatic approach which emphasises: that software can be changed; that the impetus for change is unpredictable; and that hence excessive up-front planning for change can be a waste of time. If we substitute "too much planning for *change*" with "too much planning for *reuse*" we have arguably a fair criticism of lengthy standards such as SCORM.

Recognition of the role of reconstruction, assembly or anything that happens after LO construction in order to enable reuse, has gained increased attention in educational technology, under the term "re-purposing" of content [9].Much of the literature currently advocates strategies for planned reuse. These strategies centre on the presumption that concepts with roots in component engineering and object technology, such as atomicity, cohesion, coupling etc., will minimize code rewriting. In fact the possibility that source code might ever need to be accessed and modified in an LO after its creation is widely ignored.

NEW THINKING ON META-DATA

There has been much research in formulating meta-data standards, and grammar-like systems called ontologies, which give meaning to the relationship between concepts. The aim of this project is the Semantic Web where ultimately intelligent software agents can *understand* web content [10].

However an interesting recent development has occurred outside of research labs on the web itself - user-generated meta-data. Unlike standards such as LOM, this type of

meta-data has no defined vocabularies or hierarchies but is generated in free form by content users [11]. So-called "Web 2.0" applications such as Flickr, del.icio.us and Last.fm, for example, allow a user to tag a webpage, photo or song with a descriptive word. If another user also chooses that word to tag the same content the system will increase the value of that word as a description. Tags are also linked to their creators, so users can discover content created by like-minded individuals. Moreover tags are related not only by their social context (their creators and users) but also by their proximity. This means that the system can suggest related content to the user. Crucially data is organised into information according to how it is actually used.

This is in contrast to rigorously pre-defined meta-data taxonomies and ontologies where elements have formally pre-defined relationships with each other. Although user-generated meta-data systems, termed folksonomies, have drawbacks, such as spelling mistakes, less disambiguation of information etc. they do have an organic property that ensures relevance and extensibility. The implications of this type of meta-data for education is an open question [12][l3][14]. However in many ways they point to some failings of technologies such as LOM.

ONLINE MATHEMATICS QUESTION BANKS

At Oscail, The National Distance Education Centre in Dublin City University, we have used SCORM to create LOs [15]. SCORM was not chosen with reuse in mind but for its data persistence mechanisms. Using SCORM allowed for more detailed resource usage information to be gathered and persisted, than was possible via default mechanisms of Virtual Learning Environments (VLEs) – in this case Moodle. Although authoring tools are maturing, developing SCORM LOs remains time-consuming. For the creation of a bank of mathematics questions, for a foundation module of an online BSc. in Information Technology, a more rapid development toolset was required.

One option considered was Computer Algebra Systems (CAS). In theory these systems allow for very rapid generation of questions [16]. The web version of Mathematica and the open source STACK system were both looked at. Both systems are hugely powerful and offer considerable benefits however the Mathematica license fees are prohibitive while the open source STACK system is still a relatively immature technology. Moreover neither of these can be simply integrated with the VLE (both requiring separate student authentication for instance).

A RAPID QUESTION GENERATION PROCESS

Instead, a lightweight approach was adopted. Questions were developed in Moodle's GIFT format. GIFT is a simple mark-up format for creating questions and importing them into Moodle from text files. GIFT has a very small syntax and only a handful of rules yet it allows for several question types including multiple choice (MCQ) and numeric input which were both used here.

Moodle has native support for the mathematics languages TeX and LaTeX. Moodle accepts LaTeX input, outputting a gif image of the resultant expression (with the code preserved in the image's alt text). LaTeX expressions can also be used in GIFT

questions. Some LaTeX control characters need to be escaped when embedding in GIFT but GIFT is itself very simple with only seven special characters.
One advantage of CAS is the ability to create questions with random parameters and automatically computed answers [17]. This allows each student a unique set of questions useful for reducing potential plagiarism. The questions are similar in form so all students get questions of similar difficulty. This functionality was simulated in an Excel spreadsheet using the *Analysis Toolpak* add-in. This add-in allowed for simple formulae to be inserted into workbooks to, for example, generate random numbers from ranges. The bounds of a range can be specified in separate cells. This illustrates some of the advantages of using spreadsheets for this task:

- Spreadsheets are convenient for presenting data in a friendly format
- Spreadsheets are well understood by many people (i.e. non-software developers)

More advanced formulae were also used such as to perform basic matrix algebra operations but the use of full-blown programming/scripting language was avoided.

The workbooks were arranged so that separate cells at the top of the worksheet showed:

- The question stem
- The range from which the question parameters would be randomly generated
- Ranges for foils (wrong answers) for MCQs
- The LaTeX code, if any, required to render the question

Then a row was shown for each question with cells showing

- Each foil (for MCQs)
- The correct answer
- Concatenation of these parts (question stem/foils/answer) into a valid GIFT string

Multiple questions were then generated simply by using the *auto-fill* feature of Excel where formulae are replicated by dragging cells. Each question had the same form but differing parameters and answers, which were automatically computed. The output was exported to a text file and imported into Moodle to a new question category. This process was repeated to generate as many questions as needed. Next a Moodle quiz was created with the instruction to add one random question from each of the categories.

Using this simple method a bank of several hundred unique questions, based on seventeen basic forms, was created.

QUESTION REUSE

The questions were developed to leverage technologies and platforms that are widely-used and have favourable licensing. A Moodle function allows them to be exported easily in the QTI format. Questions can also be shared in GIFT through the Moodle.org Question Exchange. More fundamentally the process can be shared with practitioners because of its simplicity through for example workshops, one of which has been given. All outputs are also being shared in Ireland's National Digital Learning Repository (NDLR) through the Mathematics and Statistics Service Teaching Community of Practice.

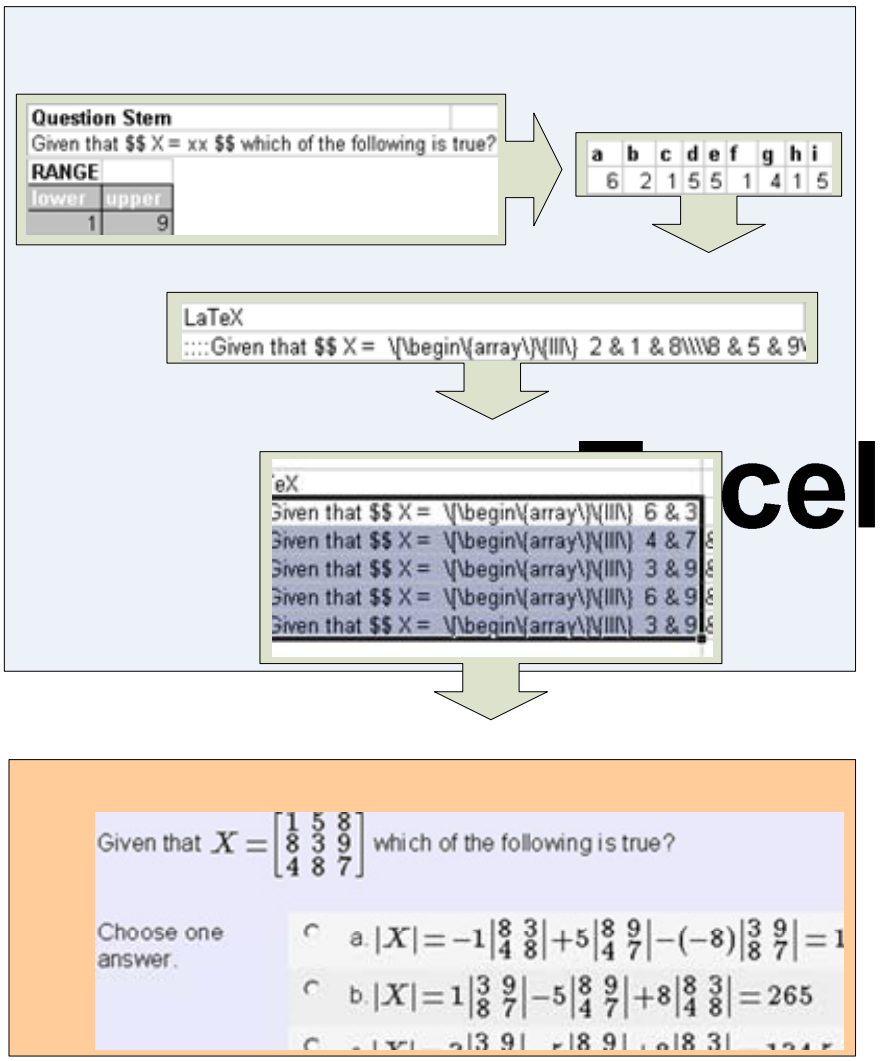

Figure 1: Question generation workflow

Little provision was made for classical LO reusability during development. Annotation, documentation, and meta-data were not added. The real provision for reuse is that the questions were designed to be simply understood and easily changed from their *source files* which are themselves being shared through the NDLR. The development of the questions is rapid once the (straight-forward) process has been understood. Philosophically this is similar to Agile software methodologies where the allure of reuse is traded for lean software which can be rapidly generated from a reusable process.

CONCLUSION

Pedagogical theories have looked at the contextualisation issues surrounding reuse and standards such as SCORM have gained attention as methods of highly systematic reuse. Realising actual reuse is not straightforward and has been a known problem in software engineering, albeit not identical to the pedagogical one. Developments in software engineering such as Agile methods have advocated leaner process models more focused on the present than the future. This spirit informed the process presented here for rapid generation of mathematics question banks.

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