A Framework for Higher Education

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Abstract: - It is well documented that the traditional protocol for higher education doesn't suit each learner, the rhetorical method of lecturing while presupposing certain domain knowledge and experience is a very inefficient method of imparting knowledge. An ideal solution is to have a one-to-one system, where an instructor generates mathemagenic content for each learner. Obviously this is not an ideal situation considering the high increase of learners into higher education. One solution is for higher education to partially traverse into an online learning environment with an element of suitable adaptive content. Adaptive learning systems attempt to adapt learning content to suit the needs of the learners using the system. Most adaptive techniques however are constrained by the pedagogical preference of the author of the system and are always constrained to the system they were developed for and the domain content. This paper describes a personal profile that can be used to automatically generate instructional content to suit the pedagogical preference and cognitive ability of a learner in a tractable amount of time. The paper discusses the manifestation of measurable cognitive traits in an online learning environment and identifies cognitive resources that can be used to stimulate these manifestations. Additionally this paper describes a Content Analyser that is used to automatically generate Metadata to encapsulate cognitive resources within instructional content. The content is repackaged as independent Sharable Content Objects (SCOs) as described by the Sharable Content Object Reference Model. Finally the paper concludes with an example learning component that utilizes the CA for building course content to an expected predetermined minimum learning experience suited to each learner's cognitive ability and pedagogical preference delivered through Moodle.

Key-Words: - SCORM, Content Adaptation, Selection Model, Content Analyser, Moodle, Digital Repositories.

1 Introduction

The number of people entering into higher education is increasing at an incredible pace. It is estimated that currently there are approximately 70 million people in higher education and that this number will more than double before 2025 [1]. It has been suggested by Sir John Daniel that to cope with this alarming increase entry into higher education, a new university would have to be opened every week [2]. Obviously this is not a feasible option.

A number of studies have been carried out on teaching environments and the effects on the participating students [3] and have shown that in a typical classroom environment every student, on average, asks about 0.1 questions every hour. The speed with which different students can progress through instruction varies by factors of three to seven [4]. With individual tutoring, students may ask or answer on average 120 questions per hour [4]. The achievement of individually tutored students may exceed that of classroom students by as much as two standard deviations – an improvement which is equivalent to raising the performance of 50th percentile students to that of 98th percentile students [5].

Currently, blended learning technologies such as Moodle, Blackboard and Wimba offer a wide range of functions to aid in the design of the instructional material. Other learning technologies such as Adaptive Hypermedia Systems (AHS) [6] and Intelligent Tutoring Tools (ITT) [7] are focused on developing the learning potential of a learner. In particular, AHS are designed to adapt to the needs of the learner with respect to their domain experience, while the ITT helps to develop cognitive skills. Although these learning technologies have their strengths and weaknesses, they are constrained by the pedagogical preference of the author of the learning technology and are all subject to the specific system for which they are developed.

This paper focuses on the foundation of the Advanced Distributed Learning (ADL) initiative and their production of a standardized reference model to reference instructional material as learning objects. We evaluate their goal to produce the highest quality of instructional material tailored to the individual needs of each user anytime anywhere [8]. To bridge our perceived gap between traditional adaptive learning technologies and the SCORM, an explicit consideration is taken to explore the different environmental contexts of a learning experience [9]. These include the type of learning objects, the level the knowledge is being taught at and the various methods of delivering the content to the users.

In addition to evaluating adaptation techniques and the environmental contexts of a learning experience, this paper investigates the reusability of instructional content within educational repositories, such as MERLOT, JOURAM and NDLR. The paper is mainly concerned with the introduction of a Content Analyser (CA) that enables an easy transformation to a single referencing standard that automatically generates metadata concerned with stimulating cognitive resources within an online learning environment. The paper concludes with an example learning component that uses the functionality of the CA to automatically generate instructional content for any individual learner to a predetermined minimum expected learning experience.

2 Learning Techniques

Adaptive content presentation is becoming an important part of educational philosophy dealing with the increased number of people entering into the higher educational market. This section briefly discusses different learning technologies that can aid in the deployment of instructional material and investigates AHS as the foundation of instructional adaptation.

Learning Management Systems (LMS) like Moodle and Blackboard act as a framework for educational providers to organize and deliver their instructional content in a standard way. They also offer some blended learning facilities to promote a constructivist approach to learning, for example discussion forums. No content adaptation is taken into consideration consequently these platforms only act to transfer the educational sector into an online environment.

2.1 Adaptive Hypermedia Systems

Adaptive Hypermedia systems have been in development since the early 1990s. They extend the one-size fits all approach of hypermedia systems by building a model of the users preferences, goals and knowledge and use this model throughout the interaction with the user. In constructing any AHS there are three main components: the knowledge space, the hyperspace and the student model. The knowledge space represents a collection of knowledge elements which represent concepts. The simplest construction of the knowledge space is an unconnected scatter of knowledge elements. The most common type of link is a pre-requisite link giving the author of an AHS the ability to make sure that a concept is known before the student moves onto the next concept. Semantic links have also been applied to different AHS. The hyperspace is the actual content, which is available to be presented to the user. Using some form of mapping we create a mapping between the knowledge space and the hyperspace. The student model represents the preferences, goals and knowledge of each user. A mapping is also created between the student model and the domain knowledge elements in the knowledge space.

AHS are very useful in any application area where users of the hypermedia system have essentially different goals and knowledge and where the hyperspace is reasonably large. AHS try to overcome this problem by using information stored in the user model to adapt the information and links being presented to the given user. Knowing user goals and knowledge AHS can aid in navigation by limiting browsing. Although AHS and similar learning technologies have their strengths and weaknesses, they are constrained by the pedagogical preference of the author of the learning technology and are subject to the specific system for which they are developed.

2.2 Adaptive Learning Environment

To create a truly adaptive learning environment across multiple domains the cognitive ability and the pedagogical preference of a learner should be taken into consideration (see Maycock et al. [10]). Successful adaptation requires some correlation between the environmental contexts of a learning environment and the cognitive ability of a learner. These environmental contexts include the type and delivery protocol of the learning content. Brusilovsky [11] distinguished two categories of features within a hypermedia system suitable for adaptation: content adaptation and navigation adaptation. Adaptive navigation techniques such as direct guidance, adaptive hiding or re-ordering of links, link annotation, map adaptation [12], link disabling and link removal [13] can be used to control both the size and level of the instructional space available to each learner. Adaptive content presentation operates at the domain level. The information can be adapted to various types of media and difficulty to meet the needs of each user. However, with the introduction of specifications like SCORM, enhanced adaptive content presentation is possible given the fine granularity of learning objects.

2.2.1 Adapting to cognitive resources

Kinshuk et al. discuss the possible resources that can be adapted to suit the cognitive needs of a learner in a formalization of Exploration Space Control (ESC) [14]. They propose that the structure of the learning content should change depending on the ability of a learner. However, it is now argued by Laurillard [15] that the structure of the learning content embodies the meaning of the learning content. We believe that it should not be possible for an adaptive learning environment to change the structure of learning content thereby potentially changing the meaning of the content and subsequently changing the potential learning experience [16]. Kinshuk et al. [14] believe that the reduction of sensory resources describing an instructional object depends on the ability of a learner. In 1956, Miller [17] reviewed the current research to determine the Working Memory Capacity (WMC) of an individual and found that an individual could store between 5 and 9 items in their WMC for one-dimensional content. It was also discovered that when the number of dimensions describing the content increases, the amount of items that can be stored in the WMC of an individual increases exponentially. We believe however, that an adaptive learning environment should not reduce the number of dimensions, potentially the WMC of a learner throughout a learning experience.

Resources \ CT	WMC		IRA		IPS		ALS	
	High	Low	High	Low	High	Low	High	Low
Paths	+	--	--	+	+	--	--	+
Path Relevance	--	+	\	--	--	+	--	+
Amount of Info	+	--	--	+	+	--	\	\

Table 1: Illustrating the optimal adaptation between resources used in learning objects and suitable cognitive traits.

Table 1, adapted from [14], shows how resources in a learning environment can be adapted to suit the cognitive ability of a learner and in particular shows the relationships and correlations between WMC, Information Processing Speed (IPS) and Associative Learning Skill (ASL). In Table 1 the '+' symbol indicates an increase in the number of resources to adapt to the cognitive ability, the '-' symbol indicates a decrease in the number of resources to adapt to the cognitive ability and the '\' symbol indicates no change in the number of resources required to adapt to the cognitive ability of a learner. If a learner has been categorised to have high WMC then for the purposes of adapting to the number of paths, relevance of paths and the amount of information, the learner would be classified to having low Inductive Reasoning Ability (IRA) and high IPS. Similarly, if a learner has been categorized as having low WMC then for the purposes of adapting to the number of paths, relevance of paths and the amount of information, the learner would be classified as having high IRA and low IPS. Different types of media transmit certain kinds of information better than others. Audio information stimulates imagination, while spatial visualization is better interpreted visually [18]. It has also been found that diagrams are better at conveying ideas and text is better for detail [19].

Content developers are responsible for producing small granular learning objects that adequately describe a domain concept. Each learning object that is created should take into consideration the different types of media and their optimal effect on a learning experience. The following section discusses manifestations of suitable cognitive abilities of a learner and details how SCORM learning content can be adapted to automatically recognise these manifestations within a SCORM 2004 conformant LMS.

3 Reusable Learning Content

Adapting content to the cognitive ability of a learner requires firstly the identification of manifestations of cognitive resources and secondly large amounts of learning objects for a specified domain. The following subsections discuss possible manifestations of cognitive traits and detail problems associated with current repositories and standards.

3.1 SCORM

In November 1997, the Department of Defense (DoD) and the White House Office of Science Technology Policy (OSTP) launched the ADL initiative. The mission of the ADL was to provide access to the highest quality of education and training, tailored to the individual needs of each user anytime anywhere [8]. The ADL initiative borrowed from many different specifications and standards when developing the Sharable Content Object Reference Model (SCORM), such as: AICC, ARIADNE, IEEE LTSC and IMS. SCORM is used to produce and deploy courses that can be tracked and delivered to a student by a Learning Management System (LMS) in a standardized way.

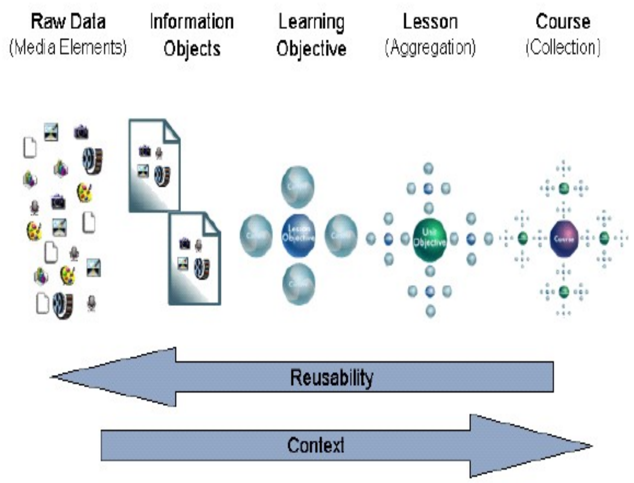

Figure 1: The reusability of SCORM components.

An LMS is software that automates training event administration through a standard set of services that; launch learning content, keeps track of learner progress and sequences learning content. Figure 1 shows the various components described by the SCORM. It illustrates the reusability of each component from raw data to complete courses.

The SCORM can be broken up into three different parts often referred to as a bookshelf. The SCORM is broken up into three different books; Content Aggregation Model (CAM), Sequencing and Navigational (SN) model and the SCORM Run Time Environment (RTE).

The CAM book fully encapsulates a learning object using XML tags and details how to package these components for reuse. The SN model defines various methods of delivering content to users. The SCORM RTE lists the requirements for a learning object interacting with a Learning Management System. Learning objects consist of assets and Sharable Content Objects (SCO). An asset can represent anything from a text file to an image or sound file. A SCO can be represented as one or more assets that must contain at least one particular asset that utilizes that SCORM RTE. In other words a SCO represents the lowest level of granularity that can be tracked by a learning management system. Figure 2 shows how Assets and SCOs can be combined to generate an aggregation of learning components, i.e. a course.

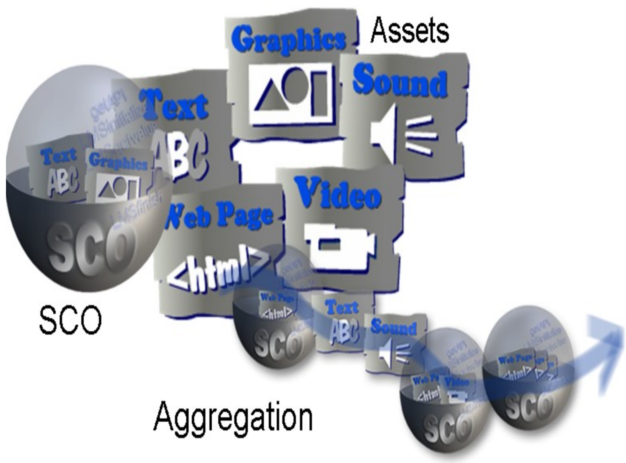

Figure 2: Generating courses using SCOs and Assets.

SCORM 2004 has four important control modes: User Choice, Flow Navigation, Choice Exit and Flow Forward Only. Once the cognitive ability of a learner has been identified and the relevant learning objects are identified the control modes of each learning object can be modified to suit the pedagogical preference of the learner. This brings the learning experience to the zone of proximal development for each learner. When User Choice is selected, the learner is then free to choose any learning object within the information space. This type of learning would suit a holistic learner, enabling the learner to freely navigate through the learning space. As the learning space would already have been adapted to suit the learner's cognitive ability, this would reduce the possibility of the learner becoming 'lost' in hyperspace. In the case of Flow Navigation, the LMS determines the next activity to deliver with respect to the learners' navigation request. The learning object delivered is determined by the objectives set out within the sequencing and navigation for that particular SCO. This type of learning environment would suit an atomistic learner constrained by their interactions with the learning environment. When Choice Exit is disabled, the learner cannot choose another activity while the current activity is still in progress. This type of learning environment could be implemented in conjunction with User Choice or Flow Navigation to make sure that all activities are completed. This would also be useful when a content developer is delivering formative assessment for a particular activity. Flow Forward Only restricts a learner from revisiting a previously visited learning object (User Choice must be disabled).

The environmental contexts of a learning environment that were found to be optimal for adapting to the cognitive ability of a learner are: the type of media, the number of paths, the relevance of paths the amount of information and the readability level of the information. These resources should be described within the Learning Object Meta data (LOM) section of each SCORM conformant learning object.

3.2.1 3.2 Manifestations of Cognitive Traits

The cognitive traits of a learner that we consider to be optimal for adapting learning content to are: Working Memory Capacity, Inductive Reasoning Ability, Information Processing Speed and Associative Learning Skill. For each cognitive trait, we have chosen identifiable manifestations that can be incorporated into SCORM learning content to enable automatic detection of cognitive traits by a LMS. Working Memory Capacity (WMC), also known as short-term storage, represents the amount of temporal storage of recently perceived information. Miller [17] showed for a one-dimensional space the WMC of a learner ranges from 5 to 9 items and also showed that WMC increases exponentially if more dimensions are added into the instructional material. Every Sharable Content Object (SCO) defined within the SCORM is complete with extensive Learning Object Meta data (LOM). This allows detection and reuse of granular learning objects incorporating multidimensional media describing the learning content. The adaptable manifestations for WMC are:

- Constantly revisiting learned materials very shortly indicates signs of low WMC [20].
- When new items enter WMC, displacement or interference may occur.
- People with a greater tolerance to interference have higher WMC [21].
- Frequently missing steps or losing components during a long sequence calculation or procedure indicate signs for low WMC [22].
- Working Memory is known to vary with age [23].
- For learners with high WMC it is likely that they will follow the curriculum sequentially, thereby reducing the number of trans-state violations [24] [25] (for example moving to an unexpected state).
- There is a direct correlation between inferential ability and WMC.

A fundamental feature of SCORM is that it has a granular structure where each SCO defines one domain concept and the SCORM Run Time Environment (RTE) tracks one objective. This enables a content developer to track a learner's navigation between domain concepts and recognise low WMC. The granular structure of SCORM also reduces the possibility of interference of learning content. SCORM control modes assist enforcing navigational movements, consequently reducing the instructional space to maintain a balanced cognitive load for each learner.

Inductive Reasoning Ability (IRA) can be determined by most IQ tests and is widely accepted to be one of the important cognitive abilities related to intelligent behavior. Despite its notable relevance in intelligent behaviour, we believe that little effort has been spent on research to support a learner's IRA in Virtual Learning Environments (VLEs). Harvety [26] proposed that there are three main activities involved in inductive reasoning: data gathering, pattern finding and hypothesis generation. The adaptable manifestations for IRA are: •

- High generalization ability is a manifestation of high IRA.
- Inability to learn from analogy is a manifestation of low IRA.
- Ability to confirm and format hypotheses is a manifestation of high IRA.
- High domain knowledge is a manifestation of high IRA.
- High WMC is a manifestation of high IRA.

SCORM consists of small granular learning objects, each learning object concentrating on one concept. Generalisation as a manifestation of IRA can be detected from the navigational trace of a learner's interactions with a LMS. SGW [27] inform that the prior domain knowledge influences the inductive behaviour of the learner. The educational history section of a learner's personal profile as proposed by Maycock and Keating [28] contains all the relevant information regarding the learners' domain experience. Holland [29] pointed out that analogous thinking enables one to view a novel situation using familiar concepts. When the cognitive traits of a learner are being examined, analogous parallel links can be incorporated to test IRA. As analogy presents learners with an alternative problem view it adds an additional dimension to the problem, and consequently increases the amount of information that can be potentially stored in WMC. The ability to learn from analogy as a manifestation of IRA can also be detected from the navigational trace of a learner's interactions [30]. We believe that the approach is also applicable in a SCORM environment as the navigation of the learner is traced. The ability to make comparisons is also known to be highly related to IRA and is proportional to the WMC [23].

Information Processing Speed (IPS) determines how fast learners acquire new knowledge. A learner may have such a slow IPS that the learner is unable to hold enough information in his or her own working memory to permit decoding of the overall meaning [31]. The IPS of a learner can be easily detected within a SCORM conformant course by giving a learner a set of instructions and monitoring the cmi_completion_status (data model element of the SCORM).

Associative Learning Skill (ALS) is the skill a learner has to link new knowledge to existing knowledge. Transferability of learning is regarded as an important part of how learners develop competencies. For the assessment of transferability to be fair the new concept can neither be 100% nor 0% new, thus the learner must use some pattern matching to detect the correct mental model [32]. If a learner is found to have high ASL then the LMS will use the information in the learners' educational history [28] when selecting relevant learning objects.

3.3 Learning Object Reuse

The SCORM model produces instructional content that has vast amounts of metadata, however this model like all other referencing models acts like a black box, the metadata describes what the content should be like without analysing the actual content. Furthermore an analysis was carried out on some digital repositories: NDLR, MERLOT and JOURAM and it was found that the information within these repositories was both incomplete and inconsistent. Additionally it found by Norm Friesen that only fifty nine percent of people complete keywords in SCORM compliant learning objects. This is inconceivable as the purpose of generating SCORM compliant learning objects is for content reuse.

The next section details a Content Analyser (CA) that is used to take as input some instructional content and generate SCORM compliant Sharable Content Objects (SCOs). The CA also analyses the content and generates some metadata associated with the cognitive resources within the instructional content.

4 Content Analyser (CA)

The CA is focused on bridging the gap between repositories, standards and inconsistency of learning objects. The CA was designed to automatically generate metadata that represents the cognitive resources which stimulate manifestations as discussed in *Section 3.2* within an online learning environment. This identification of cognitive resources enables on-demand content adaptation to suit cognitive resources within an online learning environment. Figure 3 shows the simple protocol of the content analyser.

Repositories contain various types of instructional content such as: text files, word documents, PDF, presentation, complete SCORM packages, SCOs etc… The CA takes as input some instructional content, decouples the content and generates Sharable Content Objects (SCOs) with added metadata to describe the type of information, the amount of information, the size of the instructional space, the readability level of the content and the VARK representation of the instructional material.

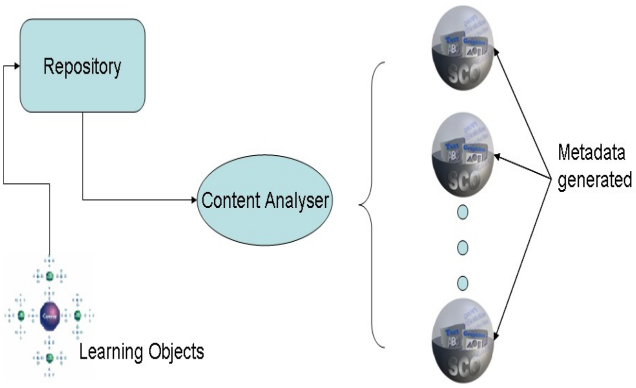

Figure 3: Content Analyser

The CA supports single file, multiple file and SCORM content as input. The CA uses the JOD JAR files to interact with OpenOffice running as a background process listening on port 8100. This allows easy transformation between different file formats.

The next section details a learning component that uses the content analyser to generate a repository of learning objects. The learning component then uses evolutionary algorithms to automatically generate instructional content for any individual to a predetermined minimum expected learning experience.

5 Learning Component distilled

Given a student profile consisting of the educational history, cognitive ability and pedagogical preference of a student we believe that it should be possible to construct a course to suit the cognitive ability and pedagogical preference of the learner.

The automated learning component resides within a compatible Sharable Content Object Reference Model (SCORM) environment as an additional component that enables content developers to develop specifications. These specifications are course templates consisting of a number of metadata files describing an author's requirements for the course content. There is no instructional information contained within the specification.

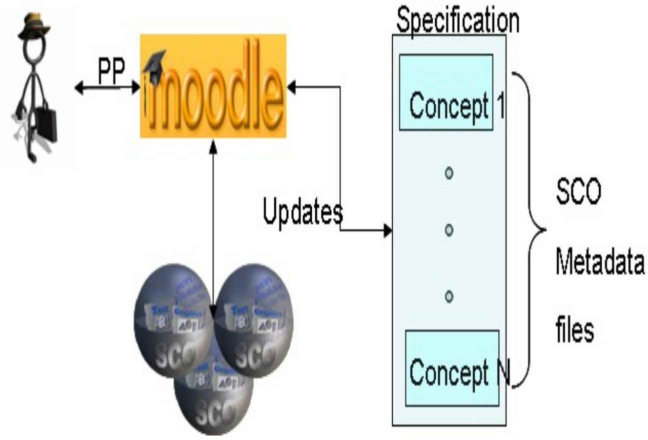

Figure 3: Architecture of Learning Component

Figure 3 shows the simple interaction of a learning interacting with Moodle and selecting a specification. A learner logs into a SCORM conformant Learning Management System (LMS). Once a learner selects a specification the LMS retrieves the learner's personal profile and updates the Meta data files in the specification. The LMS uses modified genetic algorithms to populate the specification with the domain content. After each epoch of the evolutionary process an analysis is carried out on the learning content and an evaluation of the current course offering is generated with respect to the learner's cognitive ability and the learner's pedagogical preference. The evolutionary process concludes once a course has been generated to suit a predefined expected minimum learning experience defined by the author of the specification. An analysis of the genetic operators for the Selection model can be found in [33].

The following section includes an analysis of the effectiveness of the genetic algorithm to generate sample courses using a sample population.

5.1 Effectiveness of the Selection Model

A sample population of learning objects was generated to test the genetic algorithm. This population consisted of 20 different concepts each containing 1000 randomly generated LOM files to mimic a real world problem where the full learning space is not available. A specification was randomly selected from the population with an expected minimum learning experience of 71.2%. The specification contained 8 learning objects. The genetic algorithm was run 100 times. On average the genetic algorithm took 43502 milliseconds to run for 10000 epochs. The maximum obtainable fitness value that an individual in the population can attain is 56 (for 100 % expected minimum learning experience.), however as the limit was set for 71.2 % the expected fitness value is 40. The best five iterations ran to a maximum fitness value of 40+ in less than 100 epochs, taken on average 435.02 milliseconds. An analysis was carried out on the courses that were developed and it was found that in all iterations the genetic algorithm was successfully able to identify suitable learning objects within 1000 epochs for the selected interval.

5.2 Learning Component inside Moodle

Initially the learning component will be tested using Moodle 1.7.1. Figure 4 shows the first step in generating a specification within the Moodle environment. The initial fields that are completed act to identify the specification and will form the basis of creating a directory structure and a summary page.

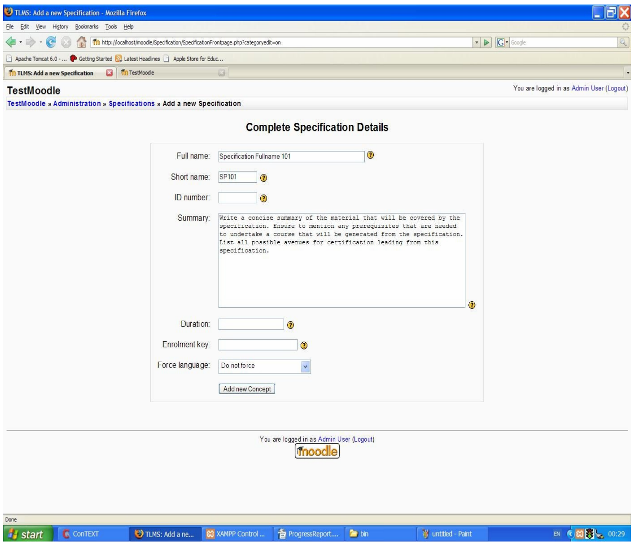

Figure 4: Generating a Specification

Figure 5 shows the required fields when completing a concept specification. All fields must conform to the SCORM standard and details are given by the help icon at each field input. The author can choose to add a new concept or generate the specification. On either selection an XML file is generated representing the requirements for the concept.

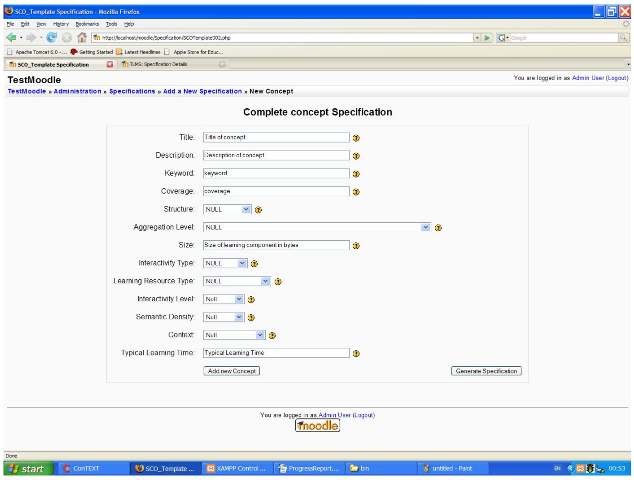

Figure 5: Generating a concept

6 Conclusion

In conclusion, to design an effective adaptive learning component the cognitive ability and pedagogical preference of a learner should be known. The current standards for referencing instructional content should include information relating to the cognitive ability of a learner. A standard referencing model should be adapted by digital repositories to maintain a level of consistency for learning object reuse. The Content Analyser that was discussed in this paper bridges the perceived gap between the repositories and the traditional approaches to content adaptation. The paper also discussed a novel approach to content adaptation, where a single specification is generated by an author and can be modified over any SCORM 2004 conformant LMS to generate a course suited to the cognitive ability and pedagogic preference of a learner.

It was also found that a genetic algorithm using a mutation rate of 8%, Rank and Truncation selection and gene repair incorporated into a genetic algorithm was found to be most optimal for finding isomorphism between learning objects. This enables the automatic generation of a course to suit the cognitive needs and pedagogic preference of each individual learner and ensures that the course is optimal for that particular learner's interactions with the LMS. Moodle 1.7.1 does not conform to the complete SCORM data model specification; consequently all courses will be run at an external location to the Moodle environment using the sample ADL RTE version 1.3.3.

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