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Personalisation for All: Making Adaptive Course Composition Easy

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ABSTRACT

The goal of personalised eLearning is to support e-learning content, activities and collaboration, adapted to the specific needs and influenced by specific preferences of the learner and built on sound pedagogic strategies. One of the major challenges to the mainstream adoption of personalised eLearning is the complexity and time involved in composing the adaptive learning experience. The key goal in personalized eLearning development tools is to sup-port the teacher in composing adaptive and non-adaptive eLearning experiences. One of the arguments of this paper is that these learning experiences should be activity-oriented and pedagogically driven. Presented is a detailed discussion of the challenges of composing adaptive courses and in particular the difficulties and possible techniques in composing appropriate models and information to support adaptive courses. The paper describes an adaptive course construction methodology which extends traditional eLearning syllabi development with design activities which support adaptivity definition, subject matter concept modelling, adaptivity technique selection as well as alternative instructional design template customisation. The paper then details the Adaptive Course Construction Toolkit (ACCT), which supports this methodology and illustrates the tools usage in the development of an adaptive course. Finally the paper presents an initial evaluation of the toolkit and its associated methodology.

Keywords

Adaptive course composition tools, Adaptive educational hypermedia systems, Personalised eLearning, Adaptive hypermedia, Metadata modelling

Introduction

Adaptive, personalized eLearning offers an important alternative to the 'one size fits all' approach of online learning [Brusilovsky (2001), Brusilovsky (1998)]. More specifically it offers the potential to uniquely address the specific learning goals [Kaplan et al. (1993)], prior knowledge [Milosavljevic (1997)] and context of a learner so as to improve that learner's satisfaction with the course and motivation to complete that course. However, authoring such adaptive (intelligent) courses has typically been a very complex, time consuming and expensive task [De Bra et. al. (2003) Eklund et. al. (1999)]. Successful personalisable courses, developed using intelligent tutoring technology, tend to have been developed as 'once off' offerings or developed as research vehicles. Intelligent Tutoring Systems (ITS) have failed to be adopted as a mainstream approach to personalized eLearning in higher education, further education or secondary/tertiary education due their inflexibility and composition costs. In order to ensure scalable, practical take up of adaptive personalisable courses, two challenges need to be addressed. Firstly the architecture for such dynamically personalized courses needs to ensure the clear separation between the 'adaptive engine or player' which dynamically composes the adaptive course, and the model(s) and content from which the personalized courses are generated. The architectural separation of the (multiple) models which can be used to generate personalized eLearning courses is explained in [Conlan et. al. (2002), Dagger et. al. (2003)]. Elements of this architectural separation of content and model can also be seen in the AHAM architecture [De Bra et. al. (2002)] and the LAOS and LAG architectures [Cristea & Kinshuk (2003), Cristea (2004)]. The second challenge to address is the need for simple, pedagogically based approaches to composing adaptive courses which reduces complexity, increases efficiency (both in the time taken to author the adaptive course as well as in learning how to author adaptive courses) and decreases costs associated with such composition.

This paper addresses the second challenge. In particular it proposes a pedagogically sound approach to adaptively composing learning activities, subject concept sequencing and learner information specification. In particular the approach maximizes the potential for reuse of instructional models, subject domain concepts, content, and generates appropriate learner model schemas, content (SCORM based) schemas as well as generating the course narrative. In addition the approach also facilitates the scoping/constraining of the generated course via a teacher's model, where a course can vary depending on the tutor responsible for that course. The approach also offers the course com-poser essential feedback as to the structure, and possible manifestations of the course (when satisfying different types of learner) and supports verification regarding the course finally delivered.

The first section "Adaptive Course Construction Methodology" illustrates the extension of a traditional non-adaptive course composition methodology to incorporate adaptivity. The paper provides an insight into past and current personalized eLearning applications in section "Personalised eLearning". "Course Composition for Personalized eLearning" presents a detailed description of the model requirements for designing and developing adaptive personalized eLearning. The section entitled "Adaptive Course Construction Toolkit (ACCT)" illustrates an adaptive course composition tool that was built upon this methodology. "Initial Evaluation" provides a brief overview of results from the initial trials of the ACCT. "Related Works" illustrates the similarities and differences between this research and the state of the art of adaptive course authoring. Finally the "Conclusion" section will provide a brief synopsis of the paper and outline some of the future research being carried out in the area of adaptive course composition and future development of the ACCT.

Adaptive Course Construction Methodology

The development of any course typically follows a syllabus authoring process which provides curriculum alignment of Learning Goals, Leaning Objectives and the Assessment techniques by which those goals and objectives are to be assessed. The curriculum then aligns the subject matter appropriate for the course with the expressed goals, objectives and assessment. Finally teaching or instructional strategies appropriate for the aligned curriculum and an evaluation strategy to ensure continuous course/syllabus improvement are designed. The development process for an aligned curriculum is iterative meaning that typically there is refinement of the goals, objectives, assessment, instructional strategy, subject matter and evaluation so as to ensure a consistent, yet deliverable course. This iterative development process is depicted in Figure 1, within the inner development methodology.

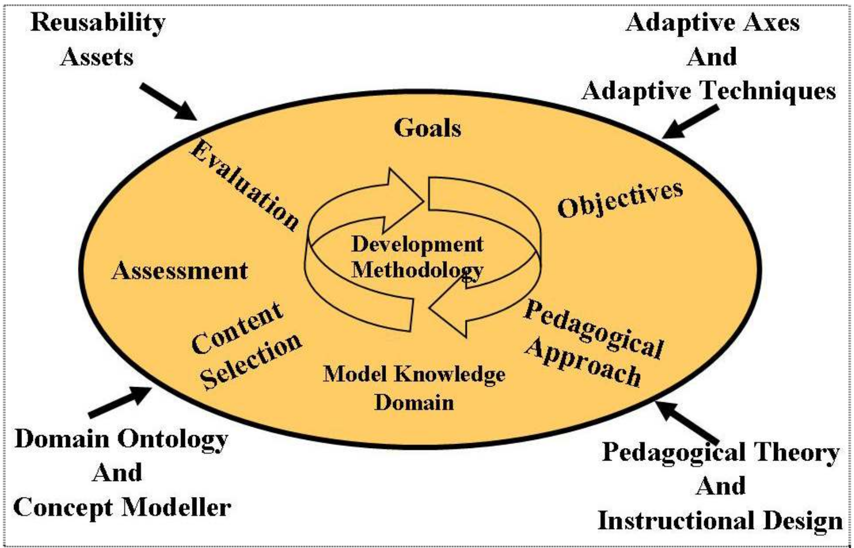

Figure 1. A Sample Adaptive Course Construction Methodology

However, in developing an 'adaptive course construction methodology', this traditional development methodology must be enhanced. Specifically, the methodology must (i) facilitate the specification of different types of adaptivity to be embedded in the design e.g. adaptivity based on prior knowledge, context, etc., (ii) facilitate the reuse and modification of one or more instructional designs, (iii) facilitate the identification of subject concepts and (iv) encourage the reuse of content assets or model elements. The adaptive course construction methodology should support the course composer in identifying what parts of the course need to be adapted, and what criteria should be used for this adaptivity. For example the course composer should be able to specify that the entire course be adaptable based on the learners' prior knowledge, but that specific activities (e.g. a discussion) should be based on the learners' preferred communication or collaboration style.

Thus the adaptive course construction methodology supports the iterative refinement of the adaptive course. It does not specify the EXACT content to be selected, but rather defines the subject matter concepts and adaptive properties on which content selection should be based.

However, we believe in an active learning approach, one in which the authoring of a course involves the authoring of activities and supplementing these activities with appropriate subject matter concepts, tools and assessments. Therefore as well as supporting the selection and sequencing of subject matter concepts (from domain ontology or subject matter concept space), we believe it is critical that the methodology supports selection and sequencing of learning activities. Such activities could include simple activities e.g. learner discussion and communication, assignment submission as well as more complex activities e.g. peer review, student election/voting etc. Such activities should be aligned with the instructional design and pedagogic strategy of the course. The course composer should be able to either specify these activities as mandatory or have them adaptively selected in the same way that other elements of the course are adaptive.

Personalized eLearning

Learning delivered online, referred to as eLearning, gives learners a self-controlled learning experience via a computer terminal. However, eLearning courses can suffer from *one size fits all* [Conklin (1987)], whereby each learner receives an identical eLearning experience. Such eLearning offerings have witnessed high drop out rates as learners become increasingly dissatisfied with courses that do not engage them [Meister (2002), Frankola (2001)]. Such high drop out rates and lack of learner satisfaction are due to the fact that most current eLearning offerings deliver the same static content to all learners, irrespective of their prior knowledge, experience, preferences or goals.

Adaptive Hypermedia (AH) [Brusilovsky (2001)] solutions have been used as possible approaches to address this dissatisfaction by attempting to personalise the learning experience for the learner. Such systems may tailor the educational offerings to the learner's objectives [Kaplan et al. (1993), Grunst (1993), Vassileva (1996)], prior knowledge [Milosavljevic (1997), Hockemeyer et al. (1998), Kayama & Okamoto (1998)], learning style [Gilbert & Han (1999), Specht & Oppermann (1998)], experience [Pérez et al. (1995), Vassileva (1996)] and many more characteristics of the learner. eLearning systems that tailor the learning experience to each individual learner are termed Personalized eLearning systems. Personalized eLearning employs an active learning strategy which empowers the learner to be in control of the context, pace and scope of their learning experience. It supports the learner by providing tools and mechanisms through which they can personalize their learning experience. This learner empowerment and shift in learning responsibility can help to improve learner satisfaction with the learning experience.

While there tends to be a clean separation of the learner model and content model in Adaptive Hypermedia Systems (AHS), the instructional approach utilized is rarely separated from the adaptive engine at the core of the systems. This means that there is either no explicit and separate instructional model or that this model is embedded in the content, learner model or in the adaptive engine itself. This lack of separation makes it difficult to repurpose personalized eLearning courses based on AHS. In particular, extending the scope or limiting the scope of such courses becomes difficult. Educators must use the complete AHS, or none of it. To support the development of flexible personalized courses the multi-model metadata driven approach, developed at Trinity College, Dublin [Conlan et. al. (2002)], explicitly separates the elements of adaptivity. These elements of adaptivity represent the instructional model, content, learner, tutor and concept domain. Through reconciling these elements of adaptivity at runtime a personalized course offering may be produced for each individual learner.

Figure 2, shows a personalized eLearning service combining information about the learner, tutor, instructional model, concept domain and content to produce a personalized course. This personalized course is tailored to particular characteristics of the learner. It is also tailored in accordance with the tutor's wishes. For example, the personalized course may be tailored to the learner's prior knowledge of a subject matter, but the maximum (or minimum) scope of the course may be defined by the tutor.

Two of the predominant difficulties with authoring and building adaptive personalised eLearning systems are complexity of the adaptive system and lack of course developer support for the authoring process. The restraining complexity of the course construction process can be somewhat alleviated by providing the course developer with a support-oriented environment in which they can create, test and publish adaptive courses. Some systems, for example LAMS, actively support the creation of activity based learning experiences [Dalziel

(2003)]. Theses systems however do not support the description and application of adaptivity to the created course models in order to produce an adaptive personalized eLearning experience.

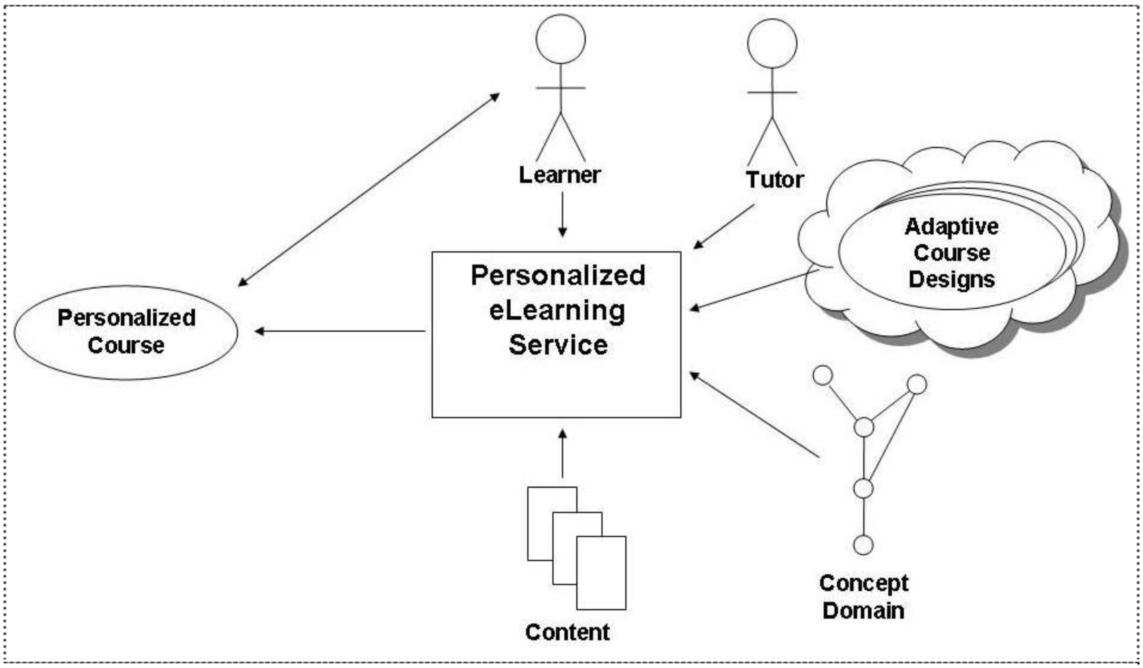

Figure 2. Combining Elements of adaptivity to produce a personalized course

A direct requirement from teachers is the ability to choose passages of a lesson which are group adaptive, to fit with a curriculumized classroom scenario, so that the information domain appears the same to all members of the "class". This type of functionality requirement can be realised by the construction of adaptive personalized eLearning experiences.

To support the construction of adaptive and non-adaptive courses this research has extended the multi-model metadata-driven approach [Conlan et. al. (2002)] to define requirements for constructs such as pedagogical modelling and adaptivity modelling. The modelling of pedagogy and adaptivity has formed the basis for Narrative Structures, Narrative Concepts and Narrative Attributes. This extension of the multi-model metadata-driven approach has led to the creation of the Adaptive Course Construction Toolkit (ACCT) which provides a course developer-oriented support framework.

Course Composition for Personalized eLearning

The composition of an adaptive course requires input from various modelled entities. Entities such as the learner, the teacher, the concept space, the pedagogical strategy(s), the learning activities, the content and the adaptive mechanisms influence the composition and realization of an adaptive course. For example, the structuring and scope of the course and the goals and objectives of the course can be influenced by both the learner and teacher. The instructional strategy of the course can be influenced by the nature of what is being learned, the goals and objectives of the course and the type of learners that will use the course. All of these models can be used as inference mechanisms by the personalized course. However the role of each of the models differs within the adaptive course composition process. In the following sections, theses models will be examined and explained in the context of the composition of an adaptive course.

Concept Space/Domain Ontology

An integral part of a course composition process is the representation of a knowledge domain. Knowledge domain representation allows the subject matter expert to model their understanding and experience of subject matter area. The Concept Space forms a logical taxonomy for the knowledge domain.

During the course composition process decisions will be made based on the information maintained in this model. Each element in the model is a concept. For each concept there is a name, a description, a list of related concepts and a list of potential candidate learning resources [Dagger et. al (2003)]. For example, information stored in the concept can be used while making decisions based on learner's competencies.

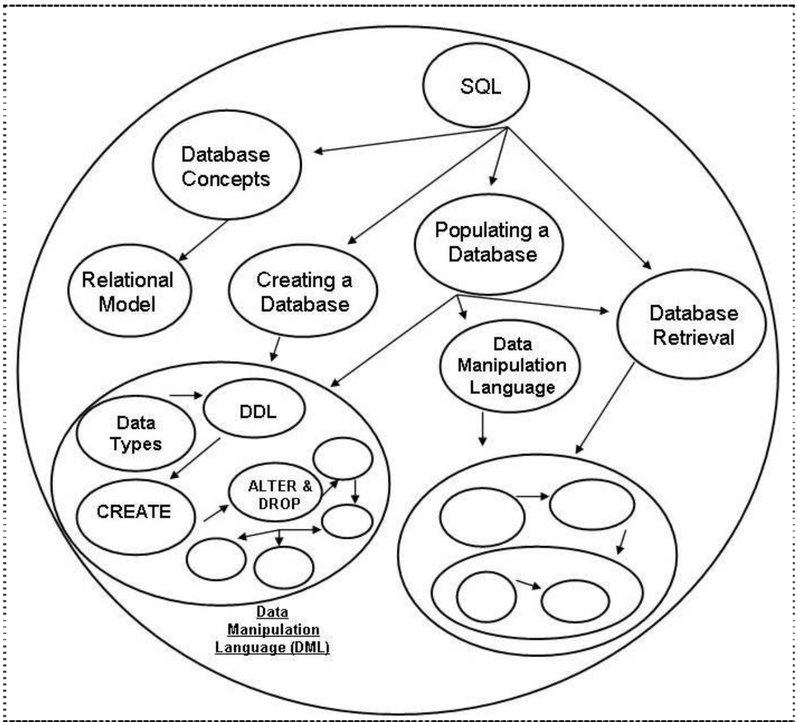

Figure 3. Logical view of a Subject Matter ConceptSpace

Figure 3 illustrates the organisation of a sample ConceptSpace based on the domain of Structured Query Language (SQL). It shows the visual representation of concepts within the space and the relationships between these concepts. From figure 3 we can see that the concept SQL has a relationship with the concepts Database Retrieval, Populating a Database, Creating a Database, etc. This relationship is depicted by the unidirectional arrows in the concept space. Relationship types can be defined to customise the semantic logic of the concept space. For example, if two concepts are related by competency levels, the semantics encapsulated in the relationship can be reasoned upon when adapting a course based on a learner's prior knowledge.

Narrative

The Narrative Model captures the semantics of the pedagogical strategy employed by a course. It describes the logic behind the selection and delivery of learning activities/concepts within the scope of a course. Using the narrative, the adaptive course can be personalized towards the goals and objectives of the learner, the preferred learning style of the learner, the prior knowledge and learning history of the learner and the context in which they are learning [Clarke et. al. (2003)].

The Narrative Model is the mechanism through which the separation of intelligence (adaptivity) and content is realized. This separation increases the potential for the reuse of the learning resources involved, i.e. the content, the intelligence and the teaching strategies. It does not reference physical learning resources instead it references Candidate Content Groups (CCG) [Dagger et. al. (2003)]. CCG are used to group pedagogically and semantically similar learning resources into virtual groups from which the Narrative Model, during execution, can reference and use.

The Narrative is used during the reconciliation of the multiple models used by the multi-model metadata-driven approach to adaptivity. For example, the learner model can be used to make candidate selection decisions based on the characteristics and learning preferences of the learner. The tutor model is reconciled by the Narrative to specify scoping boundaries on the subject matter concept space/domain ontology. This notion of bounding course scope gives the tutor the flexibility to use the same narrative across different classes or different groups within a single class, while concurrently producing differently scoped courses. The candidate content groups are used by the narrative during the candidate selection process, whereby the narrative chooses the most appropriate candidate(s) to deliver to the learner.

Narrative Concepts

Narrative Concepts are used to create conceptual containers for elements of narrative structures. They are organized to provide a detailed description of a narrative domain in terms of learning activities. Narrative Concepts are concepts that are utilized within the narrative description process. An example of a Narrative Concept (learning activity) might be "Observation and Discussion". This activity may use resources and tools that are simulation-based and collaboration-based. While the simulation-based resources may be adapted based on learning style preferences, the collaboration-based resources may be adapted based on the learners' environmental characteristics for example, device availability and network characteristics. This flexibility allows the course developer to rapidly build adaptive courses which contain both simple and complex storylines (plots).

Narrative Attributes

Narrative Attributes consist of adaptive axes, adaptive techniques, associated descriptions and usage guidelines as illustrated in figure 4. Adaptive Axes are high-level descriptions of learner and learning environment characteristics to which narrative concepts can be adapted. For example, an Adaptive Axis may describe adaptation based on a learner's prior knowledge of a subject matter area, learner's goals and objectives, learner's communication needs or learner's learning style preferences. Adaptive Techniques are the low-level mechanisms which adaptive axes can use to perform an adaptive task. For example, through the adaptive axis "prior knowledge", the course composer my wish to use a learning object inclusion/exclusion technique or a link hiding technique depending on the level of granularity that exists within the content-space, i.e. whether the content is "pages" or "pagelet" [Conlan et. al. (2002)] size.

Narrative Concepts are used to create the custom teaching structure for a non-adaptive online course. To make an online course adaptive, the course developer must choose which sections, concepts or learning activities they wish to be adapted to the learner. Narrative Attributes can be used to describe the behaviour of a Narrative Concept. A narrative attribute may, for example, be used to describe some adaptive context in which the Narrative Concept will exist. The course developer can associate narrative attributes with narrative concepts indicating his/her desire for these concepts to be adaptively delivered. Such associations may infer that concepts be rendered in a particular fashion, for example; adapt this concept to the visual preferences of the learner, while at the same time insuring that a set curriculum is adhered to and that the overall course is delivered based on a learner's prior knowledge.

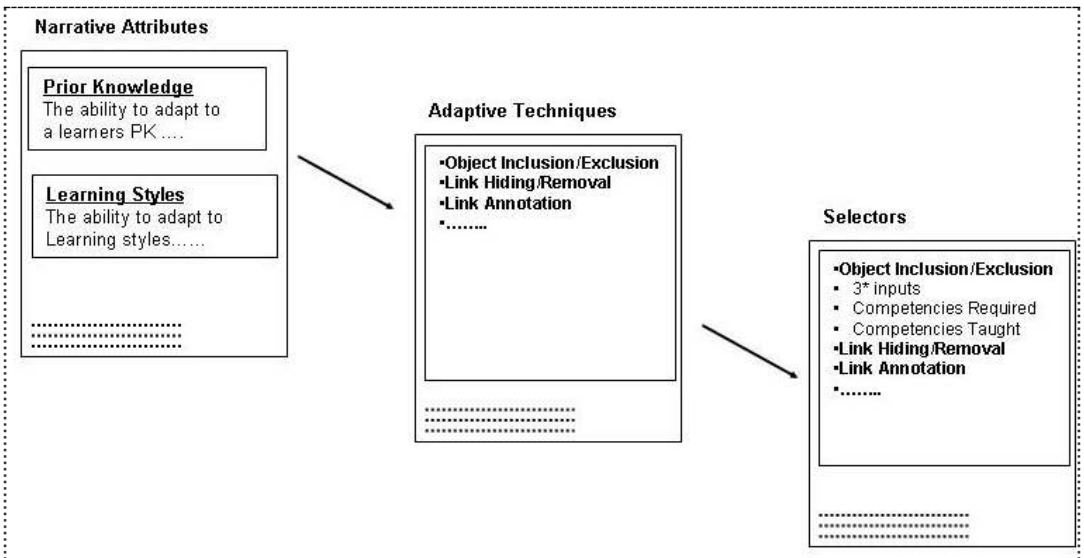

Figure 4. Logical Breakdown of Narrative Attributes

Narrative Attributes can be used, for example, to apply adaptive effects to concepts based on learner characteristics, tutor characteristics, learning context and device specifications. Narrative Attributes are key elements in the conversion of a non-adaptive online course to a personalized adaptive online course.

Figure 4 illustrates the logical hierarchy of Narrative Attributes. For example, the Narrative Attribute "Prior Knowledge" describes what the attribute is capable of performing, a set of usage guidelines for when and how this should be used and a group of candidate Adaptive Techniques to use. The Adaptive Techniques describe the type of hypermedia adaptation mechanisms available, for example "object inclusion", "link hiding" and "link annotating". The Adaptive Techniques reference a set of potential learning resource candidate selectors that may be used. The selectors are functionally exposed through a service-based architecture. Selectors are passed a list of parameters to reason across, for example, the return type of the selector, the ontological elements to reason across and potentially infinite other parameters. From this hierarchy it can be noted that as the course composers becomes more comfortable with the adaptive course composition process he/she can more directly specify the types of adaptive techniques to employ or even the type of candidate selector to use.

Narrative Structures

Instructional Design Principles, Pedagogical and Andragogical theory formalize and describe learning and teaching strategies. Narrative Structures are a model-based representation of theses descriptions. The models can be used as templates when constructing an online course and the descriptions can be presented as usage guidelines for the strategy. The combination of guideline and model can be used during reconciliation and validation of the online course.

Narrative Structures are used to provide the course developer with a solid foundation, based on sound pedagogical and instructional design principles, from which to build their online course. These models are interpreted to produce real-time support for the course developer. This support forms a framework for the online course based on the selected narrative structure(s). The use of Narrative Structures allows the course developer to produce online learning based on single or multiple instructional design principles. For example, the course developer could be assembling a course on "How to teach online". The general course structure may follow a didactic approach, however within the scope of this course their may be lessons that are best taught using different pedagogical approaches, e.g. a mini case study or a web-quest.

One key challenge of online learning is to facilitate the reuse of all learning resources within a knowledge domain. Narrative Structures are formalized metadata models outlining the general narrative concepts and the flow of narrative concepts outlined by a particular instructional design strategy. They can be used in whole or as part of a customized teaching strategy. They offer guideline support to the course developer by offering usability information. Narrative structures can then be used by course developers to share their particular teaching strategy for a domain of information.

Actors

During the process of specifying and creating an adaptive/non-adaptive course there are two major roles which influence the composition of the course, the learner and the tutor. The desired effects from each and modelling principals are quite different yet both are equally important to the learning experience. The role of the learner is fundamental to an active learning pedagogy which specifies a learner-centric, constructivist learning environment. The tutor is fundamentally involved with forming the scope of, providing guidance to and defining the learning objectives of the learning experience.

The illustration in figure 5 shows the input types, based on learner and teacher involvement, that influence the learning experience. The learner model captures information about the prior knowledge, competencies, goals and capabilities of the learner while the teacher model captures information about preferred teaching strategies and learning goals. Both of these models are queried during the composition of the learning experience.

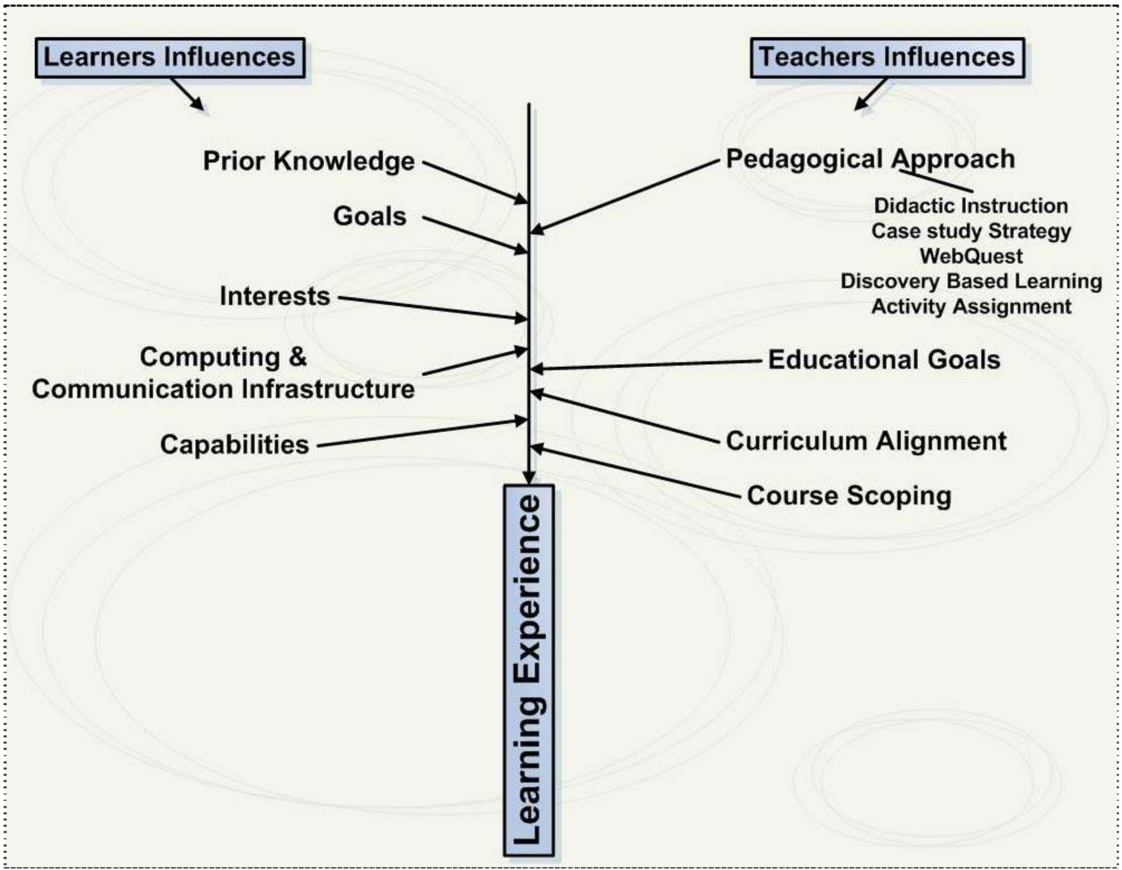

Figure 5. Influential factors in the Learning Experience

Learner

Constructivism involves the learner becoming active and interactive within their own learning experiences to develop their own understanding of the knowledge domain [Jonassen (1999)]. One key goal of the multi-model approach to personalized eLearning taken at Trinity College Dublin involves the empowerment of the learner. The learner should be in control of their learning experience and should have the capability to modify and abstract their personal learning path. Through learner empowerment [Bajraktarevic et. al. (2003)] the reach and effectiveness of adaptive personalized eLearning can be extended.

The Learner Model (LM) is defined as a schema representing the characteristics of a learner that must be modelled. The schema will define the structuring of the LM to provide a mechanism for cross-session interoperability and consistency. The ACCT will produce this LM schema which can be used when testing and publishing the course. The ACCT will update the LM schema automatically with regard to the changing characteristics of the Concept Space (Both Subject Matter and Narrative).

Since the LM is only consulted during the decision making phase of the candidate selection process, the main influence of the attributes of the LM will be the narrative concept space since it is here that the adaptive axes are applied to the narrative concepts.

Teacher

Through the ACCT the ability to empower the teacher within the learning experience can be realized using a teacher model schema. The Teacher model can be used to scope the course towards a group of learners or the curriculum of the domain ontology. It allows the course developer to specify semantic boundaries around the information space. The Teacher model will also influence the learner modelling instrument. Based on recommendations made by the Teacher, the pre-course questionnaire can be dynamically generated in line with the tutor restrictions. The Teacher model will also feed into the candidate selection process, i.e. if the teacher decides that a specific concept must always be taught, adaptively taught, or never taught. The learner model would then reflect the curriculumized decisions of the teacher.

The teacher model schema can be automatically generated using the ACCT. The ACCT creates a teacher model schema by creating a translated view of the graphical Narrative Model representing the aspects of the adaptive course that be influenced by the teacher. The teacher model schema provides the foundation and structure for the teacher model allowing the course developer to place curriculumized guidelines on the adaptive course structure.

Learning Activities

With the growth in online learning, distance learning and adaptive learning, the paradigms of instructional design are evolving [Reigeluth (1999)]. In order for the learner to acquire higher order cognition skills (analysis, synthesis and evaluation), the need for instructional design which facilitates, promotes and supports activity based learning must be realized. Through online learning and eLearning we can provide a more active learning experience, promote active learner involvement and encourage self motivation.

Learning Activities typically consist of some form of task(s), associated tools which could be used to perform the task(s), and appropriate learning content. Typically Learning Activities require some intuitive sequencing of operations. This sequencing describes the flow between the sub-activities within the Learning Activity. For example, as illustrated in figure 6, a learning activity designed for "Peer Review" may involve the submission of some assignment, the review of the submitted assignment and so on. Applying this approach, Learning Activities can be structurally modelled to provide reusable, scaleable and customizable units of instruction.

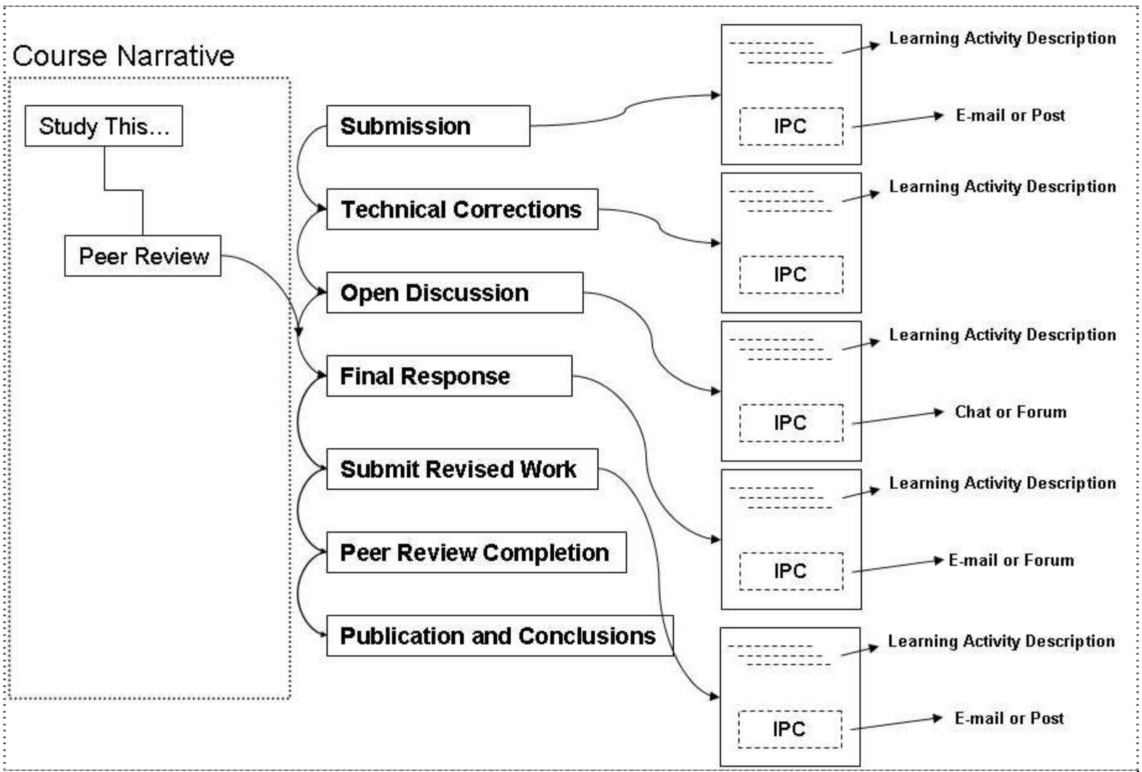

Figure 6. Learning Activity workflow within the Narrative Model

In order to flexibly incorporate Learning Activities into the personalized course composition process it was important to design a flexible and descriptive Learning Activity model. The model contains a description of the Learning Activity, the type of the Learning Activity (atomic or composite), the types of outcomes it can provide and the types of communications tools available. These activities can take the form of an atomic activity (e.g. submit an assignment) or a composite activity, i.e. a container activity for a series of atomic activities and some sequencing information (e.g. perform a peer review). Associated with an atomic activity is a description of the types of communication tools available, for example, email, chat, instant messaging, forum, etc. This flexible modelling approach increases potential for reusability, accessibility and interoperability of Learning Activities.

Currently, the ACCT supports Learning Activities in a black box form. This means that a composite Learning Activity can only be used as a whole unit. Within the coming months the flexibility of the Learning Activity model and potential for learning resource reuse will be realized with the creation of a Learning Activity composition workspace within the ACCT. This workspace will allow the course developer to create and customize Learning Activities, including the creation of control flow (sequencing) over the Learning Activity , the association of candidate communication tools and the creation of blended/hybrid Learning Activities by joining together aspects of different Learning Activities.

Adaptive Course Construction Toolkit (ACCT)

Due to the complex and dynamic process of authoring Adaptive Hypermedia, the need for author support in creating pedagogically sound adaptive personalized eLearning is evident [De Bra (2003), Brusilovsky et. al. (2002), Dagger et. al. (2003)]. From current work in adaptive hypermedia and personalized eLearning it is evident that there are two areas of research which need future development, the design of pedagogically sound courses and the support offered to the course developer during the composition of pedagogically sound courses.

This need for a pedagogical and course developer support framework has lead to the development of the Adaptive Course Construction Toolkit (ACCT). The ACCT is a design-time tool which allows the course developer to create adaptive and non-adaptive activity-oriented courses based on sound pedagogical strategies in a developer-supported environment. The ACCT provides the course developer with such tools as concept space/domain ontology builder, custom narrative builder, content package assembler, learning resource repository interactivity and a real-time course test and evaluation environment. The architecture of the ACCT is built upon a reusability-focused, developer-supported and service-oriented architecture. For example, the ACCT allows the course developer to interact with the learning resource repository, searching for candidates based on keywords and contextual prior use, through a web-service interface.

The abstraction mechanisms employed by the ACCT allow the course developer to define their teaching strategies and subject matter domains in a reusable and collaboratively supported way. This active promotion of reusability not only at the asset level but also the pedagogical, instructional design, concept and activity level will aid in the rapid construction of pedagogically sound online adaptive learning experiences.

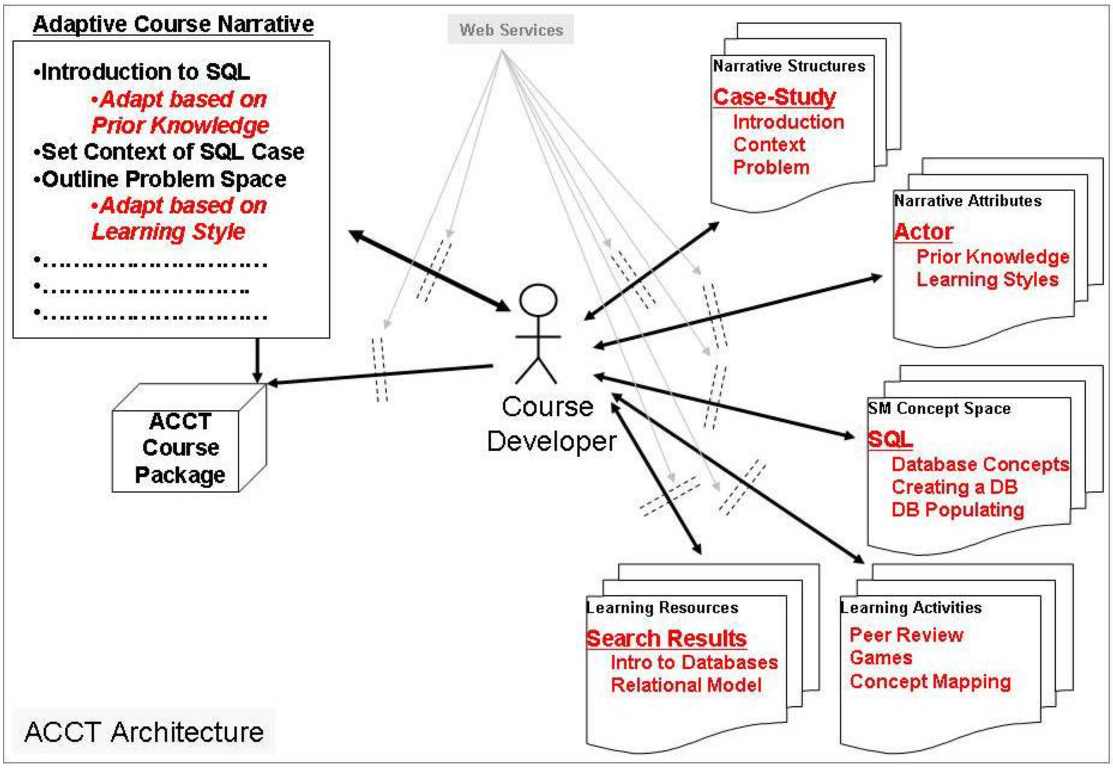

Figure 7. ACCT Architecture Model

Pedagogical and instructional design principles were studied and modelled to form reusable and scaleable design guidelines for writing narratives supported by the selected principles. The guidelines will identify and describe the abstract logic and reasoning behind the conceptual layout of the course. The guidelines are also represented in model form whereby the course developer can see and interact with the model structure during the creation of their customized course narrative. The developed model guidelines, or schema, will be translated into the model support framework for the adaptive hypermedia authoring architecture of the ACCT.

The architecture of the ACCT, as illustrated in figure 7, follows a web services paradigm. The models created by and used by the system are accessed from local/remote resource repositories. This provides access to modelled pedagogy, subject matter domain, learning activities, content and adaptivity. The course developer can then use the available modelled information to compose an adaptive course narrative.

The sample methodology in figure 1 outlines an adaptive course construction process whereby the course goals and objectives are initially identified, a pedagogical strategy(s) for the course is chosen, the subject matter domain is modelled and applied to the chosen pedagogy(s), the learning resources are selected, the adaptivity is applied to the pedagogically-based course structure and the course semantics are tested. This rapid course prototyping approach can be achieved with the ACCT as depicted in figure 7.

Subject Matter Concept Space Creation

The Subject Matter Concept Space (SMCS) is a light-weight ontology describing the relationships and interrelationships that exist within a subject matter domain. The ACCT actively supports the course developer during the creation of the SMCS through facilitating addition, deletion and modification of subject matter concepts.

The ACCT allows the course developer to describe the relationships between the concepts of the SMCS. The relationships are provided as a set of guidelines that the course developer can utilize to created relationship definitions. These relationships however can be customized. The ACCT allows the course developer to create and define new customized relationships, hence offering more control to the course developer during the course construction process.

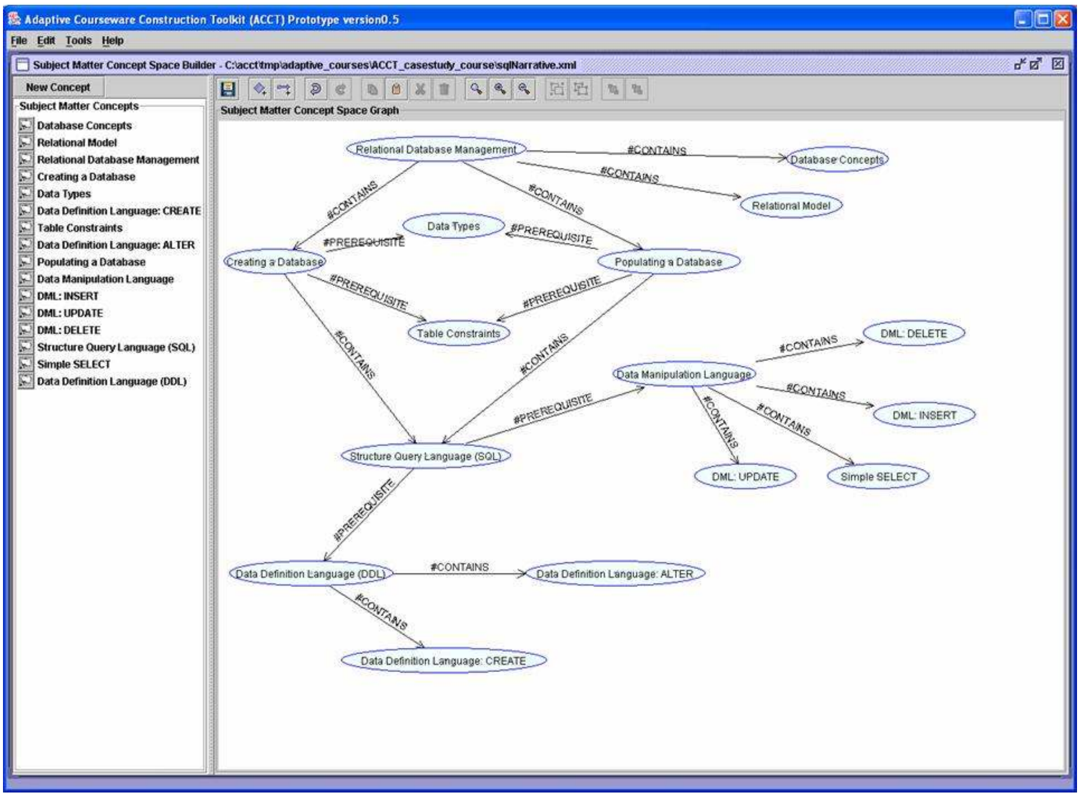

Figure 8. Designing the Subject Matter Concept Space with the ACCT

The screenshot in figure 8 depicts the subject matter concept space builder of the ACCT. It illustrates that the concepts within the space can be graphically and logically grouped with associated defined relationships. The concepts are listed on the left hand side and the logical layout is assembled on the right hand side.

Customized Narrative Model Creation

The custom narrative model builder is used by the course developer to describe the course structure in pedagogically-supported narrative terms. The course developer is supported with a drag and drop interface providing tools built from sample pedagogical models, pedagogical narrative concepts, narrative attributes, previously defined subject matter concept space model, learning activities and collaboration paradigms. A learning resource repository interaction service is provided allowing the course developer to search for learning resources.

A Narrative Structure consists of a collection of Narrative Concepts. The Narrative Concepts allow the course developer to apply aspects of pedagogical strategies to certain parts of the adaptive course. For example, the sample pedagogical model for a case-based approach might contain narrative concepts to represent learning-activities such as "The Case-study introduction", "The Context of the case-study", "The Problem to be addressed", "A collection of Resources", "A mixture of activities", "A Collection of case tools", "An Epilogue" and "Some case evaluation". By representing different pedagogical approaches as a workflow of concepts and learning activities the models provided by the ACCT become fully customizable and can be used to create hybrid pedagogies by blending different flavours of different pedagogies.

As depicted in figure 9, the ACCT pedagogically supports and guides the course developer during the design of the custom course narrative by providing a palette of fully customizable sample pedagogical models. The sample models provided are used to from the basis for the customized course narrative. Narrative Structures have been created to represent pedagogical strategies such as case-based, didactic and web-quest teaching. This approach implies that the course developer has the flexibility to apply a blend of pedagogical strategies. For example, a course on "How to Program" may follow the general didactic pedagogical strategy but certain sections within that course may better lend themselves to be taught through a case-based pedagogical strategy. This flexibility empowers the course developer with a tool that is capable of creating complex, and realistic, pedagogically-sound adaptive course offerings.

The course developer will be offered guidance on how to best use such Narrative concepts within the scope of the sample pedagogical model. Based on course developer preference, all or part of the supplied sample pedagogical model can be used. There is also a "blank" Narrative Concept which will allow the course developer to customize and expand the supplied sample pedagogical models.

While constructing a course narrative the previously defined subject matter concept space is always available in the tools palette as seen in figure 9. By dragging a subject matter concept into the graphical narrative model, its associated metadata descriptions and relationship information are made available to the Narrative. This information can be then used by any applied adaptivity.

The current version of the ACCT provides support for learning activities in unit form. Each learning activity is viewed as an atomic unit which it own internal concept descriptions, communication requirements and workflow. This atomic unit can be adapted in the same way as any other element of course. With version 2 of the ACCT, the flexibility offered by the learning activity model will be realized with the provision for a learning activity builder supporting the course developer to fully customize the provided learning activities and create new activities.

The Narrative Structures allow the course developer to build a non-adaptive narrative model based on sound pedagogical strategies. To make the narrative model adaptive the course developer must select Narrative Attributes from the available palette as illustrated in figure 9. The course developer will associate the Narrative Attribute with the Narrative Concept to which they want the adaptivity to be applied. Narrative Attributes are defined to facilitate adaptivity on axes such as prior knowledge and learning objectives, learning context, preferred learning modalities and delivery device. By "tagging" the Narrative Concept with the Narrative Attribute the course developer is saying that they would like to have this Narrative Concept taught in an adaptive way based on the adaptive axes that have been applied. The course developer is supported during this process through guideline information and sample implementation domains. The course developer can view examples and best practice information based on the current selected Narrative Attribute.

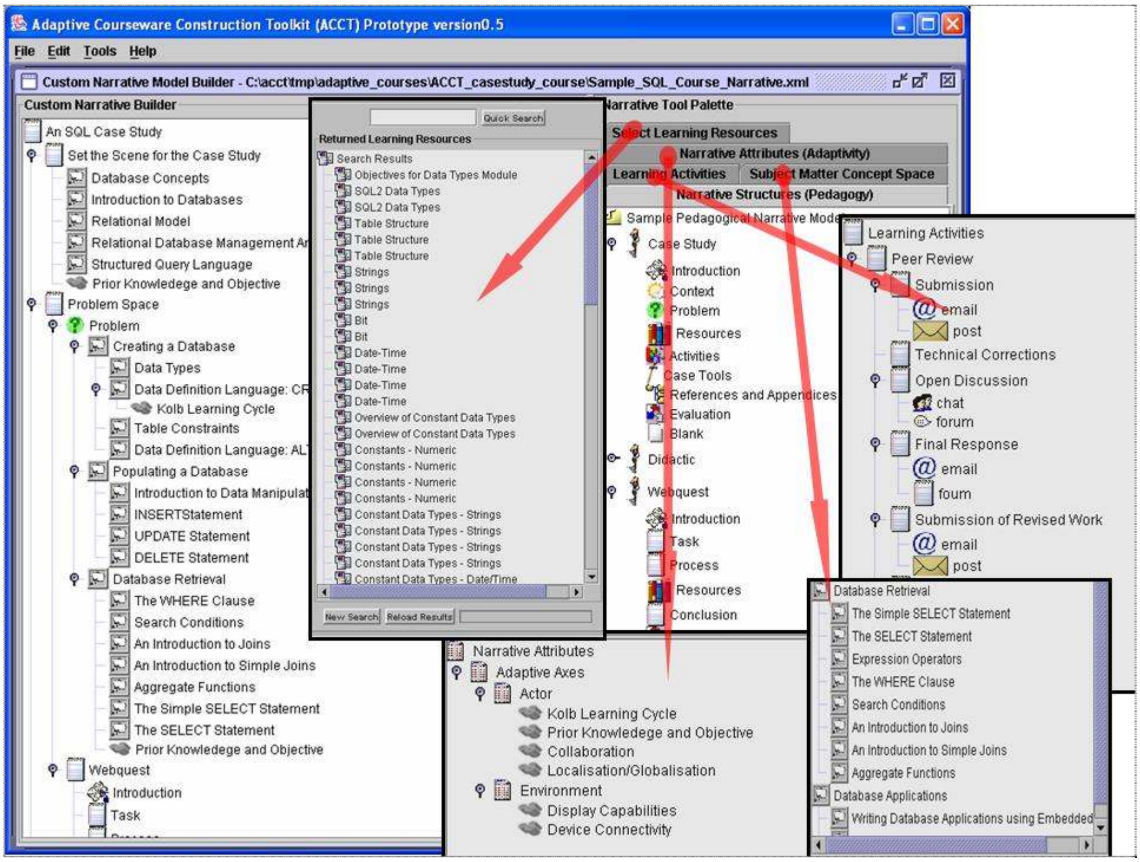

Figure 9. Building a custom Narrative using the ACCT

The ACCT has a plug-in service that allows the course developer to search across multiple remote learning resource repositories to identify and select appropriate learning resources based on keywords and prior usage information. As shown in figure 9, the ACCT actively promotes the reuse of learning resources by empowering the course developer to select learning resources from a shared repository. The course developer can then associate learning resources with the concepts of their narrative model. Multiple resources can be associated with multiple concepts. It is the role of the candidate selector to choose the appropriate candidates during the execution of the customized Narrative Model. Note that the learning resources do not necessarily have to exist. One of the features of the ACCT is to act as a content specification tool whereby the course developer can describe the concepts of the course and their context in a content-independent way. This implies that the content need not exist during the building of the ACCT courses.

Course Verification

One of the key challenges of authoring adaptive and non-adaptive courses is the ability to test the output of the course. The ACCT offers the course developer a mechanism to test, evaluate and re-develop their course through a multi-Model Metadata-driven Adaptive Engine service that can interact with and interpret the course and models produced by the ACCT.

The ACCT allows the course developer to publish their course in the form of a content package. The content package contains such information as the course manifest, subject matter concept space and relationship definitions, the custom narrative model, narrative/pedagogical structures and the narrative attributes/adaptive axes. The content package is then used during the runtime execution and reconciliation of the course allowing the course developer to test the pedagogical coherence of their adaptive course.

Initial Evaluation

The initial evaluation of the ACCT has proved very successful. The evaluation process included pedagogical and instructional design experts from the Centre for Learning Technologies at Trinity College Dublin and technology experts from the Knowledge and Data Engineering Group at Trinity College Dublin. In a workshop-based test environment, a demo of how to use the ACCT was given and a detailed explanation of the models involved in the adaptive course construction process was provided. The workshop attendees were provided with a customizable sample Concept Space, providing the subject area, in which to develop their short adaptive course.

The course developers felt empowered by the ability to efficiently create, test and deploy their short adaptive courses with the ACCT. The course developers were extremely satisfied and comfortable with making a non-adaptive course adaptive using the supplied palette of Narrative Attributes. They felt that the provided Narrative Structures (modelled pedagogy) formed a solid basis to build pedagogically sound course offerings. The ability to rapidly search for and select learning resources from multiple remote repositories promoted the reuse of the learning resources.

The ACCT has been used to develop a number of adaptive personalized eLearning courses at Trinity College Dublin in the area of Relational Databases, Physics and Mechanics. In these area's a number of adaptive eLearning courses already exist. The courses produced by the ACCT proved as technically effective as the existing hand-developed courses. The main noticeable difference was the course development timeline. The initial trials indicate that the ACCT can significantly reduce the development time/cost of creating adaptive personalized eLearning (even with the existing content). Phase two of the evaluation is currently underway at the IT Innovation Centre at Intel Ireland.

Related Works

In order to evaluate this research, a brief review of the state of the art is presented here which illustrates the similarities and the differences between the ACCT and the reviewed systems.

Current Adaptive Hypermedia (AH) systems and authoring tools for AH, in the educational domain, concentrate on developing and providing adaptive content retrieval and display capabilities. To this, adaptive content retrieval/delivery, elements of pedagogy are added in an effort to create online adaptive learning. For educationally effective adaptive eLearning however, the pedagogy must be the focus of development. Once the pedagogy has been customized (i.e. selected and extended if required) based on the subject matter area and learner goals, adaptivity can be applied to the pedagogically sound online course structure to produce adaptive personalized pedagogically-driven eLearning.

Currently, there are a range of tools available to create online pedagogy. For example, the REDEEM system [Ainsworth et. al. (1999)] allows the teacher to create pedagogical online courses by describing the structure and flow of the content of the course and also the sequencing of the content. It allows the teacher to divide the course into sections and describe the content that the course will use. REDEEM has been quite successful in construction courses however it supports no elements of adaptivity and dynamic personalization. From an active learning perspective the LAMS system [Dalziel (2003)], which is built upon the emergent Learning Design standard (Previously Educational Mark-up Language EML), allows the teacher to create, describe and sequence learning activities. However, LAMS likewise provides no support for adaptivity of pedagogical structure and content selection.

Adaptive Hypermedia authoring tools are a novel research area specifically in the domain of adaptive educational systems. The LAOS and LAG [Cristea & Kinshuk (2003), Cristea (2004)] adaptive hypermedia model hierarchies provide a 5-layer adaptive authoring model for adaptive hypermedia and 3-layer adaptation model respectively. Similarities that exist between ACCT and LAOS are the domain model (knowledge domain representation), and the adaptation model (both use hierarchical relationships between adaptive axes and adaptive techniques). The ACCT differs though by explicitly making the pedagogical model (Narrative) the primary focus of the course development process. Certain Pedagogical elements may be implemented in LAOS through the goals and constraints model, although they would be more focused on curriculum or course scoping.

Due to the complex and dynamic process of authoring Adaptive Hypermedia, the need for author support in creating adaptive pedagogically sound personalized eLearning is evident [De Bra et. al. (2003), Eklund & Brusilovsky (1999)]. The reach and effectiveness of adaptive personalized eLearning systems is also limited due to the cost of application development. The large initial setup cost of adaptive hypermedia is too high for the mass adoption of AHS in education. From current work in adaptive hypermedia [Aroyo et. al. (2003), Apted & Kay (2002)] in personalized eLearning it is evident that there are two areas of research which need future development, the design of pedagogically sound adaptive courses and the support offered to the course developer during the process of developing pedagogically sound adaptive courses. Pedagogy can be supported by specifying a requirements-based framework in which pedagogy can be described, used, reused and distributed in an effort to actively promote the cost reduction of adaptive course creation. The course developer can be supported by offering structural support and guideline support during the process of creating adaptive and non-adaptive courses.

Based on the state of the art in adaptive hypermedia and online pedagogy authoring, the ACCT will support and provide innovative ways of applying adaptivity to pedagogy to produce personalized eLearning.

Conclusion

The main goals of the research were three fold. Firstly we aimed at reducing the complexities of composing an adaptive course, i.e. construction the information models, applying adaptivity and testing the course. Secondly we tried to increase the efficiency of the course composition process, both in terms of the time and effort taken to compose an adaptive course and also the time taken to actually understand how to compose an adaptive course, i.e. what are the roles and affects of each of the models within the composition process. Thirdly we aimed at reducing the costs associated with composing an adaptive course i.e. the creation of learning resources such as instructional strategies, adaptivity, learning activities, concept spaces and content models.

These goals are being addressed in several different ways. Initial indications illustrate that steps towards the realization of these goals have been successful. The complexities of composing an adaptive course have potentially been reduced by facilitating the specification and representation of different compositional models such as instructional strategies, adaptivity, learning activities and subject matter representations. Through the ACCT these models can now easily be created, used, reused, shared and stored. The Subject Matter Concept Space builder greatly reduces the complexities of creating a domain ontology. The Custom Narrative Builder significantly reduces the complexities of creating adaptive course narratives by providing a palette of modelled components to use during the composition process. Through the course verification service, the complexities associated with testing course semantics have been greatly reduced. This reduction in complexity, inevitably leads to a decrease in the cost associated with composing an adaptive course. However, the ability to produce more efficient and more effective adaptive learning experiences using the ACCT has not yet been evaluated.

To identify the potential benefits of this research we have established a programme of trials over a two year period. Firstly, there was a small scale trial consisting of subject matter experts and instructional design experts from the Centre for Learning Technologies and the Knowledge and Data Engineering Group at Trinity College Dublin. The primary focus of this trial was the usability of the tool. The Second phase of evaluation is due to start in the middle of November 2004 at Intel Ireland. The audience of this trial will be subject matter experts from Intel's Performance Learning Solutions group and a selection of Irish secondary school teachers. Again this trial will focus primarily on the usability of the tool and the understanding of the adaptive course compositional process and models involved. The third phase of evaluation will involve the development of short adaptive courses that will be tested by select student groups. This phase of evaluation will focus on the effectiveness of the learning experiences produced with the ACCT measured against a control set of hand-written adaptive courses. Resulting from the initial trial phases, several key updates were made to both the functionality and the feature set of the ACCT.

During the next phase of research and development several different aspects of adaptive course composition will be addressed. For example, we are currently developing plug-ins that will accommodate the delivery of adaptive courses created using the ACCT on any SCORM-conformant LMS. This will be achieved by interpreting an adaptive course narrative as a content package with simple sequencing. Currently, our research into the development of novel composition environments is looking at modularized composition components, for example, SVG-based composition environments. A view of taking the ACCT to the open source community is currently being researched, allowing potential course developers to customize and personalized their adaptive course design environment while improving and extending core functionality.

From this research, we have created an environment where educators can adopt personalized eLearning systems as an educational tool. By reducing the complexity of course composition, the teacher no longer has to create different models by hand-coding the appropriate mark-up. This has enabled a totally different type of course developer, one that does not need to be a technology expert or an instructional design expert. This research provides the building blocks and stepping stones to successful adoption of personalized eLearning in higher education, further education, secondary/tertiary education and corporate training.

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