# A Framework for Developing Adaptive Personalized eLearning

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**Abstract**. Developing adaptive personalized eLearning has proven to be quite expensive regarding time and cost. Typical adaptive course creation requires input from subject matter experts, pedagogical experts and technical experts. This paper describes a framework for developing adaptive personalized pedagogically sound courses in a developer-supported environment. The paper describes the Adaptive Course Construction Toolkit (ACCT) which was created to provide the course developer with tools to design, test and deploy adaptive personalised eLearning. The ACCT offers support based on pedagogy, instructional design principles, knowledge domain ontology descriptions and learning resource selection.

## Introduction

Current tools are involved with developing multimedia and the construction of online classes, i.e. class and course management. These systems are useful but their effectiveness in a constructivist-oriented learning environment is limited. The ability to create adaptive personalized eLearning in a flexible and dynamic way is needed. From our experience in adaptive personalized eLearning, a number of key principles have been noted. It is critically important that the teacher/tutor be empowered within the learning experience and not disenfranchised. As a blended teaching approach, the adaptive and personalized eLearning does not replace the teacher. It transforms and enriches their role in the learning experience. Adaptive personalized eLearning is a tool which the teacher/tutor can use to increase the potential educational effectiveness of the entire learning experience. Adaptive eLearning is not just about adaptive content retrieval and construction. It is a mixture of pedagogy, domain knowledge (subject matter expertise) and adaptivity. The production of personalized courses is realized at the concept level not content level. Specific content selection is an aspect of learning experience development that should not concern the teacher/tutor.

This paper will give a brief overview of the state of art of adaptive hypermedia (AH), AH authoring and online pedagogical development tools. The paper will introduce the Adaptive Course Construction Toolkit (ACCT). It will describe the requirements and specifications identified during the ACCT initial development process. The paper will then describe the models, interface components and services of the ACCT. The paper will then present the evaluation process and results of the initial ACCT trialing period. This paper will conclude with a brief overview of the future work in adaptive personalized eLearning development.

## 1 State of the Art in Developing Adaptive Hypermedia and Adaptive Personalized eLearning Overview

There has been significant work in the past decade on Intelligent Tutoring Systems (ITS). Theses systems employ Artificial Intelligence techniques to aid in the teaching of a domain of information. Early ITS however failed to provide the learner with significant control over their learning. They often, contrary to theory of constructivism, imposed a strict learning path. This restriction in learning path flexibility, due to a "system is always correct" mentality, is not pedagogically viable and can be quite frustrating.

In recent years Adaptive Hypermedia Systems (AH) have added some learner characteristics to the system architecture through explicit learner modeling. Through this the AHS can customize certain aspects of the course to the learner's characteristics. Early AHS offer a level of personalization to online courses in the form of simple sequencing or "Adaptivity Lite". It allows multiple learning paths to be created, then based on the learner requirements the most "appropriate" learning path is selected. Some later AHS expand this approach by allowing adaptivity to occur on more axes. These axes of adaptivity included techniques such as link hiding, link sorting, link annotation, logical object inclusion/hiding and stretch-text. Adaptive information retrieval systems like HyperDoc, HypAdapter and Adaptive learning systems like InterBook and AHA! have proven successful in the past [*Millard et. al.(2003), Hohl et. al. (1996), Eklund, Brusilovsky (1999), De Bra et. al. (2003)*]. The deficiencies with some of these educationally-oriented systems originate with their inflexible adaptivity descriptions. Most AHS combine the intelligence for delivering the learning resource adaptively, with the learning resource itself. This semantic inflexibility inhibits the reusability of the constituent learning resource outside the context of the adaptive course in which it currently exists.

From a purely educational perspective there are a range of tools that aid in the construction of 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 in sections and describe the content that the course will use. From an active learning perspective the LAMS system [*Dalziel (2003)*], which is built upon the emergent Learning Design standard (Previously Educational Markup Language EML), allows the teacher to create, describe and sequence learning activities.

Due to the complex and dynamic process of authoring Adaptive Hypermedia, the need for author support in creating adaptive and non-adaptive pedagogically sound personalized eLearning is evident [*De Bra et. al. (2003), Brusilovsky et. al. (2002)*]. 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), Kay et. al. (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.

## 2 Adaptive Course Construction Toolkit (ACCT)

The development of the Adaptive Course Construction Toolkit (ACCT) has resulted from the need for a pedagogical and adaptive course developer support framework. The ACCT is a design-time tool which allows the course developer to create adaptive and non-adaptive activity-oriented course narratives based on sound pedagogical strategies in a developer-supported environment. The ACCT supports the course developer by providing tools to create and describe the knowledge domain that they are trying to teach, to create a customized teaching strategy through this knowledge domain, to define curriculumized scoping of the domain ontology, to search and select learning resources from multiple remote repositories, to build and distribute ACCT-based course packages and to allow for real-time adaptive course verification by rendering through an Adaptive Personalized eLearning Service (APeLS). 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 ACCT uses an abstraction-based approach, similar to the multi-model metadata-driven approach, in its course construction methodology. Different levels of abstraction can be used during the creation of the adaptive or non-adaptive course to describe the course pedagogy, sections, sub-sections, activities, available tools and concepts. This abstraction mechanism allows the course developer to define their teaching strategies and information 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.

Pedagogical and instructional design principles were studied and modeled to form reusable and scaleable design guidelines. These principles were analyzed to produce 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 ACCT can interact with, interpret and create the Multiple-Models that are used by the Architecture for multi-Model Metadata-driven Adaptivity within APeLS.

### *2.1 Requirements and Specifications*

During the process of creating adaptive and non-adaptive courses using a support-based framework there are a number of requirements that must be realized. These requirements span teacher/tutor, learner/student, educational and technical needs. For example, the teacher/tutor may be concerned with the representation of the knowledge space, the learner/student may be concerned with their learning goals/objectives/learning modality, from an educational perspective the produced course should be pedagogically sound, and from a technical perspective the course construction and delivery process should be aided by automatic model generation and reconciliation. These example requirements may feed into the development process at different chronological points to produce different affects. The following sections will outline the initial requirements and specifications of developing and constructing adaptive personalized and non-adaptive courses with the Adaptive Course Construction Toolkit (ACCT).

#### 2.1.1 Teacher Requirements

Several teacher requirements need to be realized during the creation of the Adaptive Course Construction Toolkit (ACCT) to support and aid the teacher during the process of creating pedagogically sound adaptive and non-adaptive courses. The teacher/tutor must have the ability to graphically represent the domain of knowledge within which the adaptive/non-adaptive course will exist. This graphical representation of the “Concept Space” allows the subject matter expert to define an ontology of subject matter concepts. This ability to create a “space” of concept definitions, relationships and interrelationships provides the subject matter expert with a mechanism to describe the knowledge domain in logical terms. The teacher must have the ability to search for and select appropriate learning resources to populate the adaptive/non-adaptive course. They must have the ability to open and search these repositories based on key semantic and pedagogical terms. Learning resources can be pedagogical/instructional design models, narrative models, adaptive axes, content, etc.

The teacher must also have the ability to develop adaptive/non-adaptive course narratives. The course narrative represents the “conceptual flow” of the developed course. This process can exist independent of the content that will be used to render the course. This provides the course developer with the flexibility to abstractly describe and develop adaptive/non-adaptive courses.

The teacher should be supported during the Narrative development process with the availability of sample pedagogical models. These sample pedagogical models will offer the course developer support during the creation of pedagogically sound learning experiences. For example, models to represent didactic, web-quest and case-based teaching will be provided. This requirement arises from because most online learning experiences will employ a blend of pedagogical strategies (e.g. certain sections of a didactic course should be taught in a case-based way) to fulfill its goals and objectives.

Learner empowerment must coexist with teacher empowerment. The teacher must be supported during the Narrative development process with usability and usage guidelines for the provided pedagogical models. They must have the ability to define semantic conceptual scope within the course. This will provide the course developer with the ability to shrink and grow the course scope with respect to learning sessions. This scope definition mechanism gels with a curriculumized learning environment whereby for example in lecture week 1, I want the student's course to be scoped to match the goals of lecture week 1. In this way the teacher is empowered to define and mould the learner experience to their teaching goals and objectives.

#### 2.1.2 Technical Requirements

Through a study of the process of developing adaptive/non-adaptive courses, several technical requirements of adaptive/non-adaptive course construction must be realized by the ACCT including user interface design, human-computer interaction and model generation. The user interface must intuitively support the teacher/tutor during the course development process. It will support the course development process by providing interface tools to design and develop an adaptive/non-adaptive course. The current model creation process is complex and error prone. A technical requirement of adaptive course construction is the automatic generation and reconciliation of multiple models based on the course developer interaction with the user interface. The ACCT will be responsible for generating, editing, storing and retrieving all models of the course development process.

Another technical requirement of the ACCT is the generation of a multi-session workspace and course package generation mechanism. The ACCT must maintain a virtual workspace to store the models of the adaptive/non-adaptive course. This workspace is used during "course-publication" whereby the ACCT can create a course package. The course package will contain all relevant information and models that are required by the adaptive/non-adaptive course. With the growth in popularity of service-oriented architectures, the ACCT is required to provide a service-oriented interface to both repository interaction and real-time course verification. The ACCT will communicate with multiple repositories through a generic and common service interface which will define the functionality that the service can provide during interaction with the repository.

An important requirement of the ACCT is the ability to rapidly test/verify the course output based on the custom designed narrative. This realization of this requirement relies on the ability of the ACCT to communicate with an external Adaptive Engine (AE) service. The ACCT produced course must be readable and interpretable by the AE service in order to function appropriately.

#### 2.1.3 Educational Requirements

One of key educational goals of the ACCT is to support the course developer during the process of producing pedagogically sound adaptive/non-adaptive courses. The ACCT must have the ability to represent, interact with and interpret teaching strategies based on proven pedagogical and instructional design strategies. It is responsible for providing the course developer with the pedagogical support required to develop educationally effective courses. Through this functionality the ACCT must be able to interact with and interpret custom pedagogical models.

The ACCT is required to produce educationally beneficial personalized eLearning experiences. The learner must feel in control of their learning experiences when using courses developed with the ACCT. This identifies a requirement that involves the ability of the developed learning experiences to adapt to the learner through the ability to understand the learner and produce learner model schemas based on the custom course narrative. A key challenge arising from this requirement is the development of test and evaluation processes and metrics for measuring course effectiveness.

A key educational requirement of the ACCT is to take a learning activity based approach. Currently most Adaptive Hypermedia Systems (AHS) in the educational domain concentrate on information retrieval and the adaptivity on the content level. The ACCT is required to support the development of adaptively delivered learning activities and services. Learning Activities, although somewhat contradictory of the traditional classroom-based learning environment where the teacher is the sole disseminator of the learning experience, involves the next-level of learner empowerment. This allows the learner to control the pace and focus of their learning while the teacher/tutor is available to provide classroom, group and individualized support. Although the LAMS [*Dalziel (2003)*] system allows from for the creation and sequencing of learning activities it does not support the creation of adaptive narrative based learning activity delivery. The ACCT is required to have the ability to produce such rich learning experiences.

### *2.2 Design and Implementation (Adaptive Course Construction Toolkit)*

Based on the requirements specification process, a number of models and interface aspects were designed and developed. The following sections will describe the models and the interface that was developed based on the previously defined requirements.

### 2.2.1 Models

Deficiencies of current approaches to Adaptive Hypermedia System (AHS) development involve the combining of content and intelligence that describes the adaptive delivery of the content [*De Bra et. al. (2003), Brusilovsky et. al. (2002)*]. The multi-Model Metadata-driven approach separates the content from the rules that govern its adaptive delivery [*Conlan, et. al. (2002)*]. This separation of concerns increases the potential for reuse, not only of the content but also the intelligence (pedagogy, ConceptSpace and narrative structure) behind how to adaptively deliver such content.

To facilitate flexibility and reusability in the design and implementation of new course offerings the multi-model approach was designed to include an abstraction layer. This layer, extended through the research by the ACCT, enables design-time peer-collaboration during the development of an adaptive course. For example, the abstraction enables the course author (knowledge domain expert) to develop a teaching strategy describing the course sequencing not in terms of the learning resources to be added, but in terms of the concepts or learning activities to be learned, i.e. content-independent course development.

The models used will extend the standardized models of eLearning, namely IMS LRM, IEEE LOM and ADL SCORM. One of the key attributes of creating educationally and adaptively effective metadata is not to record the similarities of the educational or adaptive values of the learning resource being modeled but the differences. The de facto standards are extended to accommodate educationally and adaptively differentiating descriptions that can be reconciled during the decision making of the narrative execution process. This is achieved through the use of the "adaptivity_type" element. It provides pedagogical and adaptable information, about the learning resource being modeled, which the narrative can interpret at runtime. An example of which can be seen in fig.???

```
<adaptivity>
<adaptivity_type name=" adaptiveaxes.actor.learninggoal">
        <description>A learning goal describes the following……</description>
        <candidate>To gain a full understanding of this concept</candidate>
        <candidate>To be able to……</candidate>
</adaptivity_type>
</adaptivity>
```

**Fig. 1**

#### 2.2.1.1 Subject Matter Concept Space (SMCS)

One of the key challenges of the adaptive course construction process is to identify and represent the abstract domain of information within which the adaptive course will exist. The SMCS is the embodiment of this scaffolding of the domain knowledge. Through the use of the subject matter concept space the subject matter expert can describe the information domain to be taught as a collection of high level concept descriptions, relationships and interrelationships in a content-independent way. This ability to describe the information domain in a content-independent way provides the course developer with a mechanism to rapidly prototype ACCT-developed adaptive/non-adaptive course structures.

```
<concept id="2" type="subjectmatter" xlink:href="2">
  <name lang="en">Database Concepts</name>
  <description lang="en" >This concept will introduce the learner to Database Concept</description>
 <relationships>
 <relationship xlink:href="3">
  <relationship_type xlink:href="#FOLLOWEDBY" />
  <relationship_cardinality xlink:href="1-1" />
  <relationship_description xlink:href="en">Conceptual sequencing should place the "Creating a DB" concept after "Database
Concepts"</relationship_description>
 </relationship>
</relationships>
 <adapt />
 <candidates />
</concept>
```

**Fig 2**, a sample SMCS representing relational databases, illustrates that the concept "Database Concepts" is described to introduce "Database Concepts" to the learner while indicating that it has a single relationship within the SMCS that implies that conceptually it should be "FollowedBy" the concept "Creating a DB". These descriptions and relationship definitions allow the subject matter expert the ability to build an ontology representing the information domain.

#### 2.2.1.2 Narrative Concepts

Narrative Concepts are used to create conceptual containers for learning activities and pedagogical processes. They can be organized to provide a detailed description of a narrative domain, i.e. the domain in which the narrative will operate. Narrative Concepts are concepts that are utilized within the narrative description process. Initially they can are used to describe a concept

that is related to an instructional design principle or pedagogical strategy. It provides a mechanism which allows the course developer to describe the purpose of a course section or learning activity independently from the physical content that it might use.

Narrative Concepts typically contain a learning activity along with some descriptive information on best use practice, scope of the learning activity and the type of adaptivity that is best suited to delivering this learning activity. For example, a learning activity might be called "Observation and Discussion". This activity may use resources and tools that are both simulation-based and collaboration-based. While the simulation-based resources may be adapted based on learning style preferences for example, visual and kinesthetic, the collaboration-based resources may be adapted based on the learners' environmental characteristics for example, device type, network type and latency and context. This flexibility allows the course developer to rapidly build adaptive/non-adaptive courses which contain both simple and complex narratives (storylines or plots).

```
<concept id="0301" type="narrative">
  <name lang="en">Introduction</name>
   <description lang="en">This document should be written with the student as the intended audience.  Write a short paragraph
     here to introduce the activity or lesson to the students. If there is a role or scenario involved (e.g., "You are a detective trying
     to identify the mysterious poet.") then here is where you'll set the stage. .....</description>
  <relationships>
    <relationship xlink:href="0302">
      <relationship_type xlink:href="#FOLLOWEDBY" />
      <relationship_cardinality xlink:href="1-1" />
      <relationship_description xlink:href="en">In a typical WebQuest pedagogical model this concept is
           followed by a concept outlining the "Task" or goals and objectives of the WebQuest
        </relationship_description>
    </relationship>
  </relationships>
  <adapt />
  <candidates />
</concept>
```

**Fig 3**, a sample Narrative Concept, illustrates that this Narrative Concept is a conceptual container for the WebQuest pedagogical concept "Introduction". To this the course developer can add and specify learning activities. This provides the first level of course development support provided by the ACCT.

### 2.2.1.3 Narrative Attributes

Narrative Attributes consists of adaptive axes, adaptive techniques, associated descriptions and usage guidelines. Adaptive Axes are high-level descriptions of learner and learning environment characteristics to which narrative concepts can be adapted. For example, Adaptive Axes may describe adaptation based on a learner's prior knowledge of the subject matter, learner's goals and objectives, learner's communication needs and learner's learning style preferences. Adaptive Techniques are the low-level mechanisms which adaptive axes can employ to fulfill an adaptive task. For example, through the adaptive axes "prior knowledge", I would like to use a learning object inclusion/exclusion technique or a link hiding technique depending on the level of granularity that exists with the content-space, i.e. whether the content is "pages" or "pagelet" 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 would like to be adapted to the learner. Narrative Attributes can be used to describe the behavior 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 their desire for this concept to be adaptively delivered. Such association 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.

```
<narrative_attribute id="00102">
  <name lang="en">Prior Knowledge and Objective</name>
  <type lang="en" ref="">adaptiveaxes.actor.knowledgespaces</type>
  <description lang="en">This can be used to request that actor-based adaptation be applied to a
      NarrativeConcept. The type of adaptivity relates to the Theory of Knowledge Spaces</description>
   <parameters>
    <param type="competencies.required">
      <restrictions type="string" use="required" />
      <description />
  </param>
    <param type="competencies.taught">
      <restrictions type="string" use="required" />
      <description />
  </param>
```

```
  </parameters>
   <relationships />
   <candidates />
</narrative_attribute>
```

**Fig 4**, a sample Narrative Attribute, describes the adaptive axes of "prior knowledge and objectives". This Narrative Attribute requires two parameters to be valid, the competencies required to learn the associated concept, i.e. Prior Knowledge, and the competencies that the associated concept is able to teach, i.e. Objectives. Note that this Narrative Attribute describes the type of learner interaction that might occur and the parameter requirements of such interaction. It does not specify how this interaction will occur. In this case the narrative execution will decide which adaptive technique to use, i.e. object related or link related, based on the supplied candidate adaptive techniques.

#### 2.2.1.4 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 second level of 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 pedagogical structure of the course may follow a didactic approach. Within the scope of this course, however, their may be lesson activities that are best taught using a case-based or a web-quest approach. Using narrative structures these pedagogical and instructional design principles can be hierarchically combined to produce the custom strategy for the online course. This allows the course developer the flexibility to develop realistic and structurally complex online courses in a support-oriented environment. Narrative structures actively promote the use and reuse of teaching strategies as they can then be used by course developers to share their particular teaching strategy for a domain of information.

```
<concept id="030" type="model" xmlns:xlink="http://www.w3.org/1999/xlink">
  <name lang="en">Webquest</name>
  <description lang="en" />
   <relationships />
  <adapt />
  <candidates />
  <concept id="0301" type="narrative">
  <name lang="en">Introduction</name>
  <description lang="en">This document should be written with the student as the intended audience. Write a short paragraph here to
     introduce the activity or lesson to the students…description>
  <relationships />
  <adapt />
  <candidates />
  </concept>
  <concept id="0302" type="narrative">
  <name lang="en">Task</name>
  <description lang="en">Describe crisply and clearly what the end result of the learners' activities will be. The task could be
     a:problem or mystery to be solved; position to be formulated and defended;…. </description>
  <relationships />
  <adapt />
  <candidates />
  </concept>
```

**Fig 5**, a sample of a Narrative Structure based on the WebQuest instructional design paradigm, describes and structures the learning activities or Narrative Concepts in sequential model form. This model for example outlines that a typical WebQuest pedagogy starts with an introduction learning activity, followed by a task learning activity, etc. The model form allows the course developer to control the ACCT when developing custom narrative models with the support of the supplied sound pedagogical models.

#### 2.2.1.5 Narrative Model

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. The narrative model can be seen as an adaptive storyline through a domain of information. With the guidance of 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.

With the separation of rules from content which increases the potential for the reuse of the learning resources involved, i.e. the content, the intelligence and the teaching strategies, the Narrative Model represents the pedagogical intelligence. It does not reference physical learning resources; instead it references Candidate Content Groups (CCG). 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. It utilizes an abstract course overview and description, pedagogically supported teaching structures, custom and generic narrative concepts, concept space (domain ontology) concepts, selected learning resources and adaptive axes descriptions to produce an adaptive course. The Narrative is responsible for the reconciliation of the multiple models used within APeLS (Adaptive Personalized eLearning Service). Through current research the Narrative Model has been extended to incorporate abstract descriptions of the types of adaptive axes reference-able by the narrative and support sample Narrative Structures/Pedagogical Models descriptions and usability guidelines. A future vision of the ACCT will involve the expansion of the notion of narrative into a service oriented environment.

```
<concept xmlns:xlink="http://www.w3.org/1999/xlink" id="1" type="narrative">
  <name lang="en">SQL Case Study</name>
  <description lang="en" />
  <relationships />
  <adapt />
  <candidates />
  <narrative_attribute id="00102">
   <name lang="en">Prior Knowledege and Objectives</name>
   <type lang="en" ref="">adaptiveaxes.actor.knowledgespaces</type>
   <description lang="en">This can be used to request that actor-based adaptation be applied to a NarrativeConcept. The type of
       adaptivity relates to the Theory of Knowledge Spaces. This ....</description>
   <parameters>
     <param type="competencies.required">
      <restrictions type="string" use="required" />
      <description />
     </param>
     <param type="competencies.taught">
      <restrictions type="string" use="required" />
     ……
```

**Fig 6**, a sample custom designed Narrative Model for an Adaptive Personalized SQL Course, indicates the logical arrangements of narrative components to produce this personalized course model. In the figure shown, it is clear that a Narrative Attribute "Prior Knowledge and Objectives" is associated with the core Narrative Concept of "SQL Case Study". This indicates that the axes of adaptivity corresponding to "Prior Knowledge and Objectives" be applied throughout the entire learning experience. This allows the course developer to define not only the course structure but also the course behavior in an easy to understand and interpretable manner.

#### 2.2.1.6 Course Package (CP)

The ACCT allows the course developer to create a course package thus accommodating the development of courses over multiple sessions, allowing collaboration in the course development process and distribution of the adaptive/non-adaptive course. The CP is where the ACCT stores the outputted Adaptive Course and associated models and learning resources. It is here that a manifest for your adaptive course is created and stored. The manifest has the postfix ".acct" attached to signify that this is a manifest for an ACCT created course. The CP also initiates a "WORKSPACE" where the course models being created are temporarily stored during normal runtime operation.

#### 2.2.1.7 Actors

Within the lifetime of a typical learning experience there are two key actors involved, the teacher/tutor and the learner. The roles played in the learning experience by the two actors differ dramatically. The teacher/tutor's role is to structure, assemble and deliver the learning. The learner's role is to understand and interact with the provided learning. In a learner-centric environment the teacher/tutor may feel disassociated from the learning experience being delivered. Although within an activity based learning environment the role of the teacher/tutor is more over a facilitator to the learners' learning. In this way the learner is more actively involved with learning experience. These traits must be represented in the final solution.

The Learner Model (LM) is defined as a schema representing the learner characteristics towards which the learning experience can adapt. The schema will define the structure 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 ConceptSpace and Custom Narrative.

Since the LM is only consulted during the decision making phase of the candidate selection process, the main influence on the elements of the LM will be the custom narrative since it is here that the adaptive axes are applied to the narrative concepts. The ACCT will be able to display the current LM schema to the course developer. The course developer can restrict this schema through the use of the tutor model.

The Tutor 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 tutor model will also influence the learner modeling instrument. Based on recommendations made by the Tutor, the pre-course questionnaire can be dynamically generated in line with the tutor restrictions. The Tutor model will also feed into the candidate selection process, i.e. if the tutor decides that a specific concept must always be taught, adaptively taught, or never taught. The learner model would then reflect the curriculumized scoping decisions of the tutor.

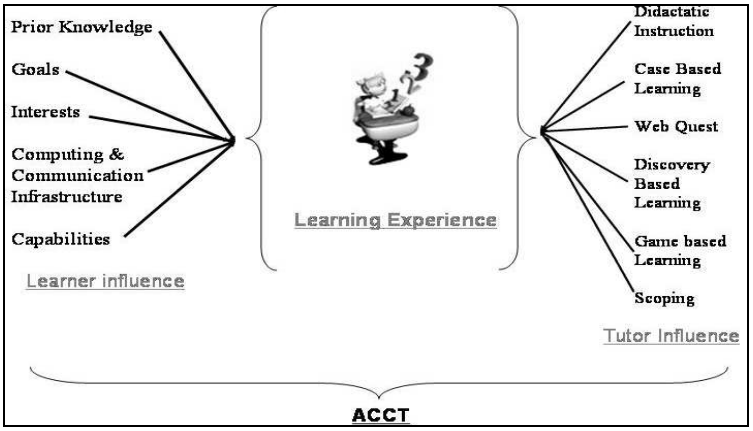


**Fig.6**

### 2.2.2 User Interface

#### 2.2.2.1 Subject Matter Concept Space Editor (SMCS)

The Subject Matter Concept Space (SMCS) is an ontology describing the relationships and interrelationships that exist within a domain of information. The SMCS allows the subject matter expert to describe the domain of information that they are trying to represent in terms that are familiar to them. This abstract semantic description of an information domain is later applied during the formation of the custom narrative.

The ACCT provides an environment where the course developer can add, delete and modify 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, however, allows the course developer to create and define new customized relationships. This flexibility to expand the available relationships offers more control to the tutor during the course development process.

The structure of the SMCS does not infer sequential relationships between the concepts of the SMCS. The SMCS simply allows the course developer or subject matter expert to create an ontology of related concepts that can be viewed, edited and used during the creation of the course narrative. The SMCS allows the course developer to abstractly describe the domain of knowledge in a non-pedagogically supported way. The course developer can apply pedagogy to the knowledge domain during the creation of the custom narrative.

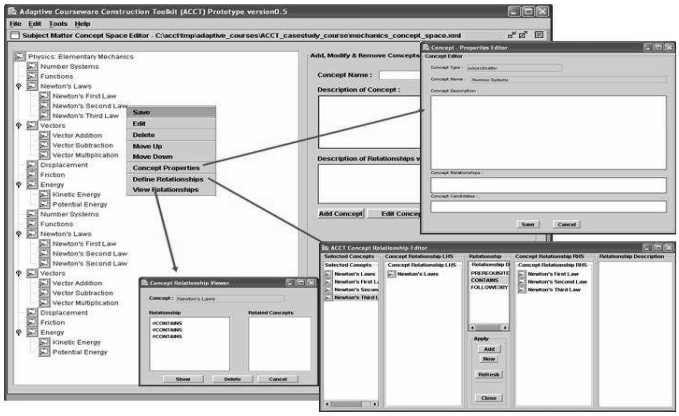

**Fig.7**

#### 2.2.2.2 Narrative Model Builder

During a course construction process the situation often arises whereby the subject matter expert is not a pedagogical, instructional design or teaching expert. The custom narrative model editor is used by the course developer to describe the course structure in pedagogically-supported narrative terms. The course developer has a palette of tools available during this process from which they can drag and drop to the custom narrative workspace. The course developer is supported with 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 open and search a learning resource repository.

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, Some case evaluation.

The course developer is pedagogically supported during this custom narrative creation process by being provided with a palette of sample pedagogical models which they can use and customize. The Narrative Structures/Pedagogical Models supplied by the ACCT provide pedagogical guidance during the creation of the course. The sample models provided are used to from the basis for the customized course narrative. This approach implies that the course developer has the flexibility to apply a blend of pedagogical strategies thus empowering the course developer to create 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. The ACCT does not restrict the course developer in any way. On the contrary it aims to empower the teacher/tutor to develop educationally effective adaptive/non-adaptive personalized online courses. By allowing a "blank" Narrative Concept, it empowers the teacher/tutor to create and customize their own personal pedagogical models either based on the provided "sample" models or newly built pedagogical models.

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 selected Narrative Attributes from the available palette. 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 associating the Narrative Concept with the Narrative Attribute the course developer is saying that he would like to have this Narrative Concept delivered in an adaptive way based on the adaptive axes that has 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.

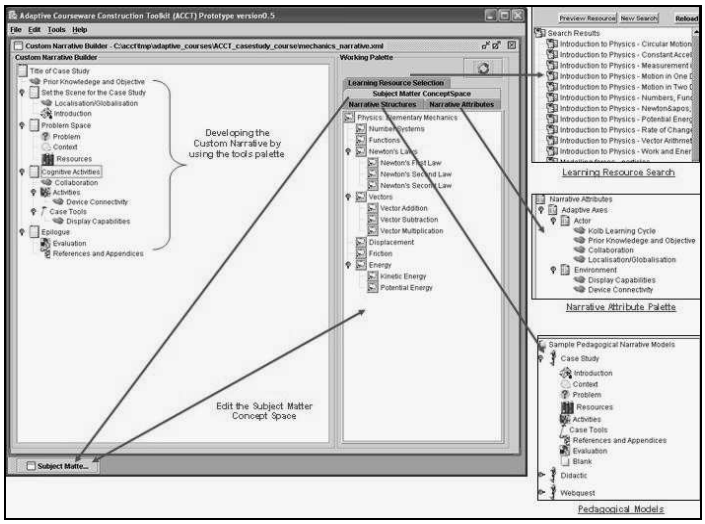


**Fig. 8**

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. 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 ACCT courses.

### 2.2.3 Course Verification

The ACCT provides the course developer with the ability to verify their course in real-time through the use of an APeLS service interface. The ACCT will publish its models through the APeLS service interface in a generic course application framework. This framework consists of learner model schema, course model, narrative model(s), JSP and XSLT to execute, generate and render the custom produced narrative model. This framework can also interact with the learning resource repository(s) through a service interface. This ability to test the adaptive course semantics in real-time is novel. This iterates the flexibility of the APeLS architecture in interpreting and generating adaptive personalized eLearning.

## 3 Evaluation

The ACCT has been used to develop a number of adaptive personalized eLearning courses in 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-created 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). The next phase of trials will consist of development based on out-house content repositories and knowledge domains, i.e. content and domains from an industry-leading company. Currently, metrics for measuring educational effectiveness are being developed and prototyped. These metrics will be applied to future ACCT-produced courses.

## Conclusion

The paper introduced novel research into the application of adaptivity to pedagogically-based eLearning experiences to support the course developer through teacher empowerment. It detailed the requirements and specifications process which led to the development of the Adaptive Course Construction Toolkit (ACCT). It described and explained the models used during the process of creating an adaptive/non-adaptive course with the ACCT. The paper described the user interface components developed based on the requirements process. The paper then describes the course verification process and concludes with a brief evaluation.

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