Interoperability for eLearning Services Management and Provision

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Abstract

Learning Objects offer flexibility and adaptability for users to request personalised information for learning. There are standards to guide the development of learning objects. However, individual developers may customise these standards for serving different purposes when defining, describing, managing and providing learning objects, which are normally stored in heterogeneous repositories. Barriers to interoperability hinder sharing of learning services and subsequently affect quality of instructional design as learners expect to be able to receive their personalised learning content. All these impose difficulties to the users in getting the right information from the right sources. This paper investigates the interoperability issues in eLearning services management and provision and presents an approach to resolve interoperability at three levels.

Key Words: interoperability, learning object, learning object metadata, learning service

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Interoperability for eLearning Services Management and Provision

1 Introduction

The rapid evolution of information technology has created opportunities to offer various software tools, protocols and standards to support eLearning where learners can engage and manage their learning. As a result, learners demand effective personalised learning support that facilitates them to achieve their learning goals, rather than merely attend learning materials that are largely pre-prepared for them. This significant change in learning requirements imposes a new learning paradigm which enables flexible mode of content configuration, adaptive delivery and effective assessment [9], [14].

In response to the paradigm shift in learning content management, industries as well as research communities have put a great deal of effort to address eLearning issues. A significant evolution on learning content design is the use of Learning Objects [12], [22] and their tagged metadata [11] that make sharing and reuse of learning resources possible. The learning objects and metadata standards create opportunities for content designers to define and describe learning services to meet their specific requirements. This leads to diverse use of learning objects. Furthermore, various content providers offer large pools of heterogeneous learning objects on the Web [29]. Although the flexibility for sharing and reuse of the objects has increased, it is merely feasible within certain groups or specific communities, who comply with pre-defined formatting, structure and semantics of learning resources [3], [4]. Barriers to interoperability in general still hinder the sharing of learning services and subsequently affect the quality of instructional design [2], [6], [19].

This paper presents an architecture of interoperability for learning services management with technical specifications. Special focus is on solutions to enable syntactic interoperability. A model of eLearning services provision, which integrates the best practice in eLearning and Web services technology for effective management of learning services, is presented for devising technical solutions to syntactic interoperability.

2 Constructivist Learning and its Impact on Learning Content Design

Constructivist learning encourages learners to acquire necessary knowledge and skills for finding meaningful solutions to the real world problems. Their leaning involves learner-centred, goal-directed and situated activities. There are experiences in the traditional classroom where constructivist learning process is practised across various subject disciplines, but to transform the constructivist learning to the eLearning environment remains challenging. There are two main reasons: 1) It requires adequate learning content design skills to ensure flexibility, reusability and interoperability to meeting learners' requirements; 2). Learning content designed must allow a sound educational purpose to enforce knowledge construction.

An effective learning content design is not driven by the advancement of technology. It has to be rooted in the sound learning theories and appropriate instructional strategies. Constructivist paradigm [10], [21] offers instructional design philosophy that guides learners to conduct and manage their personalised learning activities, and encourage collaborative and cooperative learning for critical thinking and problem-solving. Semiotic paradigm [15], [18] emphases that understanding is a subjective process where the prior knowledge affects the interpretation of a given sign, and vice versa. It is difficult to assume for all agents (i.e., learners) involved that they will derive the same association between a sign and an object, as it involves issues such as meaning, cognition, behaviour, culture and social context.

Understanding the learning process as knowledge construction based on semiotics and constructivism enables us to identify some important features of learning [16], [24]. Within the constructivist realm, knowledge is constructed through interaction with the environment in which a process of personal interpretation of the perceived world and the negotiation of meaning from multiple perspectives takes place. Constructivism advocates that there are no cause-effect relationships between the world and the learner; learning to a large extent depends on the subjective view of the learner. Semiotics promotes educational strategies that emphasise many sign systems, or many ways of knowing. Constructivism emphasises that learning emerges from the human organism in ways which conserve adaptation and organisation—learning is to apply some sort of conceptual system upon the phenomena and to bring forth a world including those phenomena. Learning is situated, and it should occur in realistic settings. The process of semiosis enables us to structure our experiences and reveal the nature and culture of our understanding. Signs as codes of experience are related to social settings where learning takes place; learning is never a private act. The constructivist approach notes that living systems survive by fitting with one another and with other aspects of the surrounding medium. These features can be incorporated into the learning content design based on an appropriate instructional strategy for eLearning.

3 Learning Services Organisation and Management

The current practice shows that to enable eLearning services management and provision, the interoperability [20], [28] needs to be addressed at three levels: Syntactic, Structural, and Semantic (see Figure 1).

These levels of interoperability are integrated and each level has its specific concerns. In the architecture described, the lower levels provide input to the upper levels. The upper levels give broader and incorporated views of lower level applications. The syntactic level focuses on individual learning services as the building blocks of learning services management. It makes distributed learning services interoperable in a machine readable manner, so that they can be transmitted and accessed by machines. Structural interoperability at the next level up provides a generic structure for managing a group of learning services in order to achieve certain learning goals. It assembles distributed learning services according to specified rules in their own subject domains. Consequently, semantic interoperability manages concepts and relationships of different subject domains and generates a conceptual view of managing multidisciplinary learning services. This level receives learning requirements, which are interpreted and transformed onto a set of parameters for learning services assembling at the structural level. Detailed descriptions of each level of interoperability are as follows.

Syntactic Interoperability: In terms of managing learning services, syntactic heterogeneity exists due to the distributed nature of learning services from different providers, who may apply different syntactic formatting for service representation and description. Users find difficulty in discovering and sharing with others' services. Once the learning services are found, reuse of these services becomes an immediate problem as they need to be reformatted or reorganised. At the syntactic level, a format of learning services in heterogeneous information sources requires compatibility. This can be achieved by marking up services in a standard manner, e.g., in XML so that machines can understand and communicate in a sensible way.

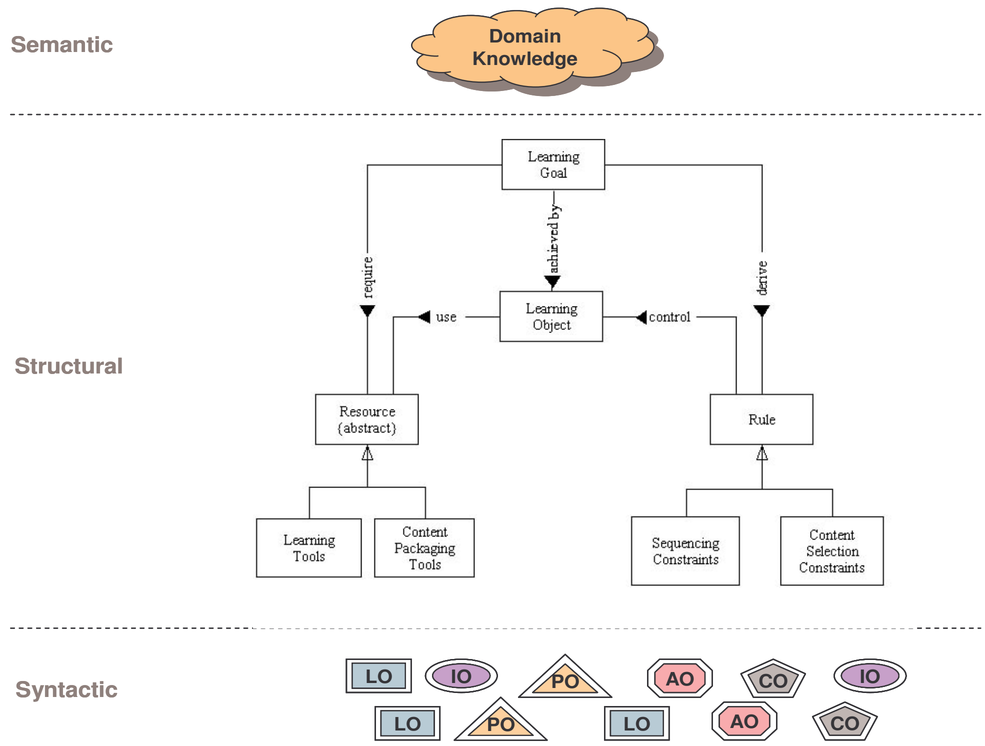

Figure 1. An Architecture of Interoperability for Learning Services Management

Structural Interoperability: Without putting learning services into a schematic structure, the sharing of learning services is still difficult. This is because certain learning services make sense to other users only when they are structured. A set of learning services have relationships within these structures to achieve certain pedagogical purposes in their subject domains. However, there is no well-known schema to model such relationships in practice for learning services management. Various individual practices follow their own ways of management, which constrains the flexibility of service reuse and sharing in a heterogeneous environment. A schematic structure (a metamodel) of learning services is required to establish rules for specifying relationships and assembling a set of learning services to achieve certain learning goals. Each instance of the metamodel falls into one subject domain, so that the assembled learning services can be discovered and shared in an appropriate context.

Semantic interoperability: Semantic ambiguity exists in terms of learning services management in multidisciplinary environments. This gives rise to different interpretation and representation of various learning requirements [7], [8]. Without an explicit specification of domain knowledge, learning services cannot be efficiently identified in an appropriate subject domain. Consequently, inappropriate information of requirements may be transformed to identify learning services at the structural level. Therefore, a conceptual model of domain knowledge is required to enforce semantic heterogeneity of learning services.

4 Design of Learning Objects for Syntactic Interoperability

Reusable learning objects developed by Cisco [5] have been successfully adopted for designing training materials in industry. Cisco describes a reusable learning object based on learning objectives which are built from a collection of static or interactive content and instructional practice activities. Each of the objects can be mixed and matched to generate courses, lessons, and instructional events. But there is lack of technical guidelines for content designers to design suitable learning objects for educational institutes. Our work has adapted Cisco's model and developed learning objects specifications which will enable sharability, accessibility, and interoperability for learning content management [24], [25].

4.1 Modelling Learning Objects

In a subject field, a module is normally defined to represent the subject, e.g., *Systems Analysis and Design with UML*, and expected learning objectives and achievements. The module contains a number of topics within the subject, e.g., *Class and Object Modelling*, *Use Case for Requirements Modelling*, and *Interaction Modelling*. To measure achievements of learning each topic, assessments are tied with the topics. There may be practicals to enforce learning. All the information describing learning materials can be transformed onto *LearningObject, InformationObject*, *ContentObject*, *PracticalObject* and *AssessmentObject*. Figure 2 shows a conceptual structure of these five types of objects with the relationships at different granularity levels.

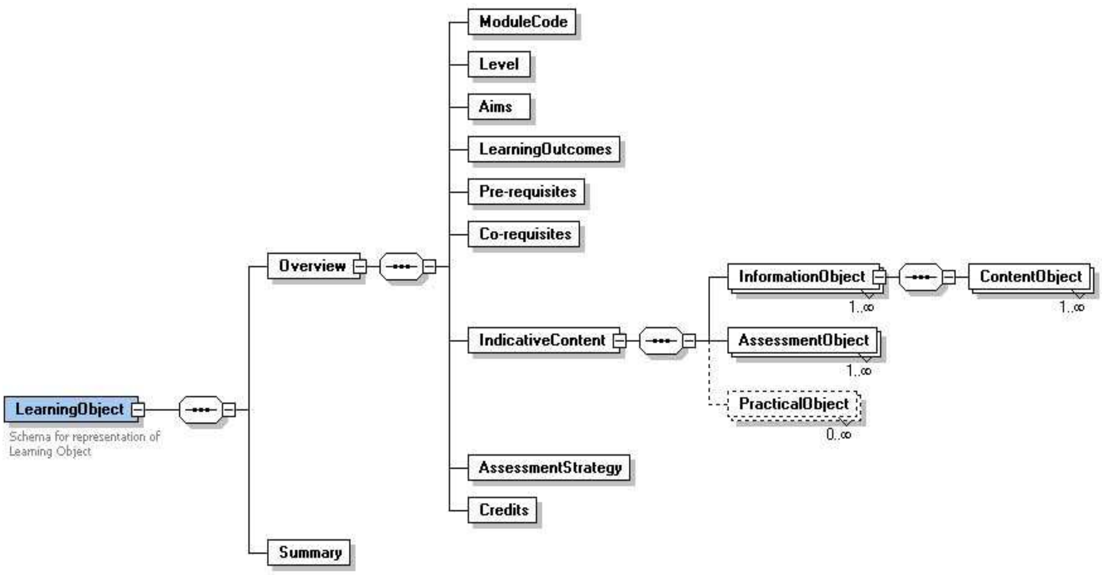

Figure 2. A Conceptual Structure of *LearningObject*

LearningObject (LO) consists of two aggregated parts: *Overview* and *Summary*. *Overview* encapsulates general information about the module, e.g., *ModulCode, Level, Aims, Pre-requisites, Co-requisites, LearningOutcomes, IndicativeContent, AssessmentStrategy*, and

Credits, which may be in the interests of various stakeholders, e.g., students, content providers, subject tutors, and accreditors. When users request a subject, they make decisions by matching their requirements with the information in *Overview* from the LO. The *Summary* part contains the subject reviews which assist students in self-assessment and self-reflection on understanding of all the topics and applying the knowledge and skills for problem solving at large. Most attributes in these two parts are simple type attributes, except *IndicativeContent* [23]. The *IndicativeContent* attribute embodies three further objects: *InformationObject*, *AssessmentObject*, and *PracticalObject*. An *InformationObject* has a `must` relationship with an *AssessmentObject*, but an `optional` relationship with a *PracticalObject*.

InformationObject (IO) is described by *Introduction*, *Concept&Principle*, and *Examples* in Figure 3. These attributes are defined as object type, i.e., *ContentObject* (CO) named as *Purpose*, *Description* and *Illustration*. The design of IO and CO comprehends pedagogical purposes and educational requirements. When learners study eLearning materials, they require clear instructions to the content and expected know-how and achievements. For example, the subject of *Systems Analysis and Design with UML* is described in the learning object LO_{ADUML}. $\mathrm{IO}_{ClObDia}$ - *Class and Object Modelling* is one of the topics in LO_{ADUML}. The *Purpose* object provides the information about specific objectives, introduction to class and object modelling, and hints & tips. This object sets a mental map for learning what class and object modelling is and the purpose of its use and technical requirements. *Purpose* should reflect to a certain extent the overall learning objectives in the LO and also guide learning. *Description*, theoretical part of the topic, contains the actual content about characteristics of classes, objects, and relationships. It also explains specific principles following which a model of objects and classes can be correctly created. From the nature of learning point of view, examples, *Illustration* of how the models can be designed for different purposes, can reinforce the understanding of the theoretical part of the topic.

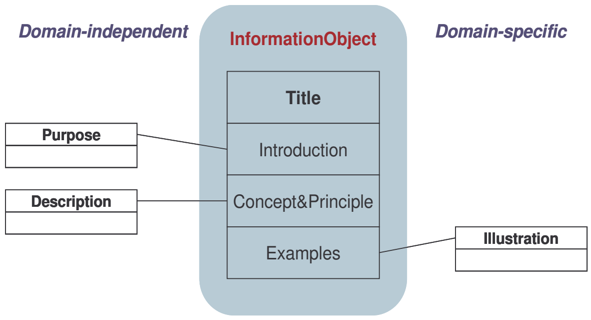

Figure 3. A Conceptual View of *InformationObject*

The learning theories and practices [10], [15], [16] show that learning is a process within which learners construct knowledge. Most learners naturally put themselves in the social and culture setting when they acquire information and construct knowledge. This kind of learning behaviour requires the content objects to be categorised into two types: `domain-independent` and `domain-specific` (see Figure 3). *Purpose* and *Description* hold the overview and theoretical aspects of the topics. They, therefore, belong to the former type. *Illustration* falls in the latter type, because the example models must present the solution to the problems which are situated in the context.

AssessmentObject (AO) is used to measure learning achievements. An AO may represent a formative assessment or a summative assessment which is determined by *AssessmentStrategy* in the LO. The AOs must be associated with the IOs within the LO. They should be designed to reflect the learning outcomes specified in the LO. An AO can be of type `domain-`

independent and domain-specific, which is dependent on its association with the CO in the IO. To associate an AO with an IO, the information about its purpose (e.g., test on theory or application) and the difficult level (e.g., at BSc – basic/advanced or MSc – basic/advanced) and domain-orientation (e.g., to overall subject or specific topic) need to be defined in the metadata.

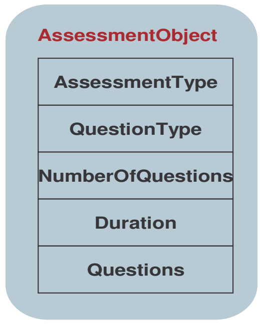

Figure 4. *AssessmentObject* Structure

PracticalObject (PO) encapsulates step-by-step technical guides for experiments and exercises required by the IOs. An appropriate design for the PO is determined by the nature of the topics, and it can be in various forms (e.g., documents in pdf form, interactive media, and movie clips). An important consideration for the PO is that it should assist learners to enhance their understanding of the topics.

```xml
<?xml version="1.0" encoding="UTF-8"?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema" elementFormDefault="qualified"
attributeFormDefault="unqualified">
    <xs:element name="LearningObject">
        <xs:annotation>
            <xs:documentation>This document describes a schema of learning objects
            </xs:documentation>
        </xs:annotation>
        <xs:complexType>
            <xs:sequence>
                <xs:element name="Overview">
                    <xs:complexType>
                        <xs:sequence>
                            <xs:element name="ModuleCode"/>
                            <xs:element name="Level"/>
                            <xs:element name="Aims"/>
                            <xs:element name="LearningOutcomes"/>
                            <xs:element name="Pre-requisites"/>
                            <xs:element name="Co-requisites"/>
                            <xs:element name="IndicativeContent">
                                <xs:complexType>
                                    <xs:sequence>
                                        <xs:element name="InformationObject" maxOccurs="unbounded">
                                            <xs:complexType>
                                                <xs:sequence>
                                                    <xs:element name="ContentObject"
                                                    maxOccurs="unbounded"/>
                                                </xs:sequence>
                                            </xs:complexType>
                                        </xs:element>
                                        <xs:element name="AssessmentObject"
                                        maxOccurs="unbounded"/>
                                        <xs:element name="PracticalObject" minOccurs="0"
                                        maxOccurs="unbounded"/>
                                    </xs:sequence>
                                </xs:complexType>
                            </xs:element>
                            <xs:element name="AssessmentStrategy"/>
                            <xs:element name="Credits"/>
                        </xs:sequence>
                    </xs:complexType>
                </xs:element>
                <xs:element name="Summary"/>
            </xs:sequence>
        </xs:complexType>
    </xs:element>
</xs:schema>
```

Figure 5. *LearningObject* Schema

All types of objects in Figure 2 are defined as learning services, which are building blocks for the design of learning content. They can be described by their schema and instantiated consistently. Therefore, the large chunk of information can be broken into the manageable forms. The schemas for *LearningObject* in Figure 5 and *InformationObject* in Figure 6 are represented.

```
<?xml version="1.0" encoding="UTF-8"?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema" elementFormDefault="qualified"
attributeFormDefault="unqualified">
    <xs:element name="InformationObject">
        <xs:annotation>
            <xs:documentation> This document describes a schema of information objects </xs:documentation>
        </xs:annotation>
        <xs:complexType>
            <xs:sequence>
                <xs:element name="Introduction"/>
                <xs:element name="ConceptPrinciple"/>
                <xs:element name="Examples"/>
            </xs:sequence>
        </xs:complexType>
    </xs:element>
</xs:schema>
```

Figure 6. *InformationObject* Schema

4.2 Application Profiles for learning objects

Learning content provision for instructional design requires efficient management of learning services. The objects' schemas are designed to capture the information content, but they will not aid discovery of these services from the heterogeneous learning content repositories. General information about learning services is normally described by metadata [11]. The current practices show that organisations and communities adopt either abbreviated version of complete standards or a mix of elements drawn from different metadata schemata. Two different ways of applying the metadata standards have raised interoperability issues. The former requires additional documentations on how terms used in various metadata schemata are constrained, encoded, and interpreted for particular purposes and establish possible mappings in between. The latter focuses on creating restriction of the elements used, designating certain elements as mandatory or optional, specifying vocabulary usage and interpretation, and adding organisation or community specific classification schemes. IMS [13] provides *Application Profiles* to address these issues.

Figure 7 shows a conceptual application profile for LO defined in Figure 5. In this profile, it consists of all categorised elements in Learning Object Metadata (LOM) [11] — `General`, `Lifecycle`, `Technical`, `Educational`, `Rights`, `Relation`, `Annotation`, and `Classification`. These selected elements can efficiently support discovery of objects for a personalised content configuration.

```
<MetaData xmlns:xsi="" xsi:noNamespaceSchemaLocation="">
    <General > general  </General>
   <Lifecycle >
           </Lifecycle>
    <Technical >
           </Technical>
    <Educational >
           </Educational>
    <Rights >
           </Rights>
    <Relation >
           </Relation>
    <Annotation>
                                        </Annotation>
    <Classification >
           </Classification>
</MetaData>
```

Figure 7. LOM Categories for LO

- `General` Category

`General` category describes the general information of learning services as a whole. We associate the value of `AggregationLevel` with the granularity of learning services—'1' as content objects, '2' as information objects and '3' as learning objects. Figure 8 shows the metadata element of an example learning object. The `AggregationLevel` attribute, the value of which is '3' specifies the granularity of a learning object. Whereas the value of `AggregationLevel` is '2', which indicates the learning service is an information object (see Figure 9).

```
<General Structure="Networked" AggregationLevel="3">
        <Identifier Entry=""http://www.rdg.ac.uk/ug/courses/132.html "' Catalog="URI"/>
        <Title>Systems Analysis and Design with UML </Title>
        <Description>The module aims to enable students to construct knowledge of systems analysis and design,
object-oriented (OO) paradigm </Description>
        <Keyword>UML</Keyword>
        <Keyword>Design method</Keyword>
    </General>
```

Figure 8. `General` for LO$_{ADUML}$

A set of learning services and their relationships can be specified in `Structure` (see Figure 8) and `Relation` (see Figure 12). `Structure` gives a general view of the way in which the involved learning services (typically information objects and content objects) are organised by a value of `atomic|collection|networked|hierarchical |linear` [11]. The value is normally determined by pedagogical instructions in a subject area. For example, in figure 8, the indicative content in the LO$_{ADUML}$ embodies IO$_{ClObDia}$, IO$_{USECASE}$, and others. These IOs contain some independent and some interrelated information. Therefore, the relationship between them can be assigned the value of `networked`.

```
<General Structure="Collection" AggregationLevel="2">
        <Identifier Entry=" http://www.rdg.ac.uk/ug/courses/23.html "/>
        <Title>Class and object modelling </Title>
        <Description>Design class model in Analysis and Design with UML</Description>
    </General>
```

Figure 9. `General` for IO$_{ClObDia}$

- `Lifecycle` Category

`Lifecycle` category describes the history and current state of the learning service. The `Contribute` tag is used to contain information of learning services providers and designers. An example is shown in Figure 10.

```
<Lifecycle Status="Draft">
        <Version>1</Version>
        <Contribute Role="Content Provider">
            <Entity>Fred Smith, The University of Reading </Entity>
            <Date>Sep. 2004</Date>
        </Contribute>
        <Contribute Role="Author">
            <Entity>Mark White, Computer Science Department, The University of Reading </Entity>
            <Date>Jan. 2004</Date>
        </Contribute>
</Lifecycle>
```

Figure 10. `Lifecycle` for LO$_{ADUML}$

- `Educational` Category

`Educational` category describes key educational or pedagogical characteristics of learning services. We associate the value of `TypicalLearningTime` with credits of a learning object to reflect its educational requirements. Figure 11 shows `TypicalLearningTime` are 50 hours learning time which is equivalent to about 5 credits.

```
<Educational InteractivityType="Expositive" LearningResourceType="NarrativeText" InteractivityLevel="Low"
SemanticDensity="Medium" IntendedEndUserRole="Learner" Context="HigherEducation" >
        <TypicalLearningTime>50 hrs</TypicalLearningTime>
        <Language>en</Language>
    </Educational>
```

Figure 11. `Educational` for LO$_{ADUML}$

- `Relation` Category

`Relation` category defines the relationship between one learning service and others. For example, IO$_{ClObDia}$ can be linked to its higher level LO$_{ADUML}$ by specifying the `Identifier` in `Relation` of LO$_{ADUML}$ (see Figure 12). The `identifier` is uniquely linked to IO$_{ClObDia}$. The `Kind` attribute of `Relation` specifies that the relationship between LO$_{ADUML}$ and IO$_{ClObDia}$ is `HasPart`.

```
<Relation Kind="HasPart">
        <Resource>
            <Identifier> http://www.rdg.ac.uk/ug/courses/23.html </Identifier>
            <Description>Class and object modelling </Description>
        </Resource>
    </Relation>
```

Figure 12. `Relation` for LO$_{ADUML}$

- `Classification` Category

The `Classification` category describes where a learning service falls within a particular classification system. This can largely facilitate learning services discovery. Currently, we use two classification systems—ACM [1] and UNSPSC [27] to categorise our learning services from discipline and educational level perspectives. Figure 13 shows the classification metadata of LO$_{ADUML.}$

```xml
<Classification Purpose="Discipline">
        <TaxonPath>
            <Source>ACM</Source>
            <Taxon>
                <Entry>Software Engineering</Entry>
            </Taxon>
        </TaxonPath>
        <Description>the 1991 Classification System is a cumulative revision of the 1982 version of the Computing
        Reviews Classification System</Description>
        <Keyword>ACM </Keyword>
    </Classification>

<Classification Purpose="EducationalLevel">
        <TaxonPath>
            <Source>UNSPSC</Source>
            <Taxon>
                <Entry>Undergraduate Programs</Entry>
            </Taxon>
        </TaxonPath>
        <Description>The United Nations Standard Products and Services Code® (UNSPSC®) provides an open,
        global multi-sector standard for efficient, accurate classification of products and services. </Description>
        <Keyword/>
</Classification>
```


Figure 13. `Classification` for LO_{ADUML}

5 Interoperability at Structural Level

The learning services are designed to be syntactically self-sufficient. They can be selected and assembled to meet different learning objectives. From a pedagogical perspective, the learning services may have relationships within certain structures. For example, when an LO is discovered, its associated resources and rules are required for assembling other objects at different granularities. Figure 2 presents a metamodel of learning objects at the Structural Level which instructs the selection of suitable objects from the heterogeneous learning content repositories.

- *Learning Goals* express overall learning aims and expected achievements. A goal must be measurable in order to support a learning process where users conduct learning activities to acquire knowledge and skills. A goal can be broken into subgoals which are associated with different learning objects that require different competences. All the achievements meeting the subgoals can be aggregated to address users' overall goals.

- *Learning Objects* are the essential part for successful learning. They represent the educational information and required achievements. Each learning object must contain at least one information object and one or more than one assessment objects. Practical objects are optional to the learning object subject to the disciplinary requirements. Each information object must include one or more than one content objects. Within the learning object, assessment objects must be associated with the information objects. Practical objects may be linked with corresponding information objects. The rules, which constrain the relationships between the objects and their granularities are specified in *Rules*. The required resources to the learning objects are defined in *Resources*.

- *Resources* are considered as an important element which indicates physical, abstract and people resources needed for designing learning objects and supporting learning. For example, Rational Rose CASE tools, as physical resource, may be required while UML is studied and practised. Certain learning objects may be in different media forms. When they are presented to users, adequate technologies are necessary. These types of resources must be specified in *Resources*.

- *Rules* define constraints, conditions and policies for how the learning objects are configured and assembled. Rules will govern selecting and sequencing learning services at the levels of learning objects, information object, assessment object, practical objects and content objects. The conditions for selecting and sequencing are determined by users' requirements.

The metamodel presents the requirement specifications and constrains which can be employed by the learning objects developers. The instances conforming to this metamodel can enforce the structural interoperability. The rules at the structural level are triggered by events from the semantic level, which addresses learning requirements and enables efficient configuration of a personalised learning package in multidisciplinary environments. The configuration process normally requires learning requirements, which include personal learning requirements (i.e., learning styles and prior knowledge) and educational learning requirements specified in an *overview* of the learning object. Personal learning requirements are conceptualised in a user profile model [26] which represents the specifications for learning content selection, sequencing and presentation. A domain knowledge model, i.e., learning services ontology, is used to signify learning requirements in appropriate subject and social contexts. Two taxonomies are applied to address educational requirements: 1) the ACM classification taxonomy for classifying subjects; 2) the local taxonomy for classifying educational degrees [1]. Technical design at the level of semantic interoperability is under testing for its validity.

6 Discovering Learning Objects for Learning Content Design

Once the learning services are syntactically described and stored in the repositories which are owned by different providers, requesting and finding them to serve instructional design become a technical issue. Web services technology has its capability for managing learning services [3], [4]. Hence, the requested LOs can be discovered efficiently.

6.1 Learning Services Provision

A model of learning services provision (see Figure 14) depicts four technical components, such as *Instructional Design, Learning Service Requestor, Learning Service Provider*, and *Learning Service Registry* [23].

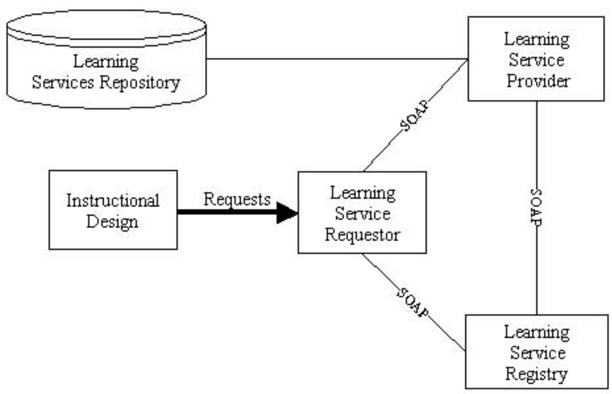

Figure 14. A Model of Learning Services Provision

Instructional Design: A first stage of instructional design process is learning requirements elicitation where learners' personal learning requirements are articulated and represented as a set of parameters, e.g., learning style and prior knowledge in the subject domain [24]. These requirements together with the educational learning requirements, such as *Level* and *Credits* defined in the *LearningObject* will form requests of appropriate learning services. However, at the syntactic level only requests from educational perspective can be matched. Personal learning requirements can be integrated by transferring an instance of the metamodel in the specific subject domain.

Learning Service Requestor: A learning service requestor receives requests from the *Instructional Design* component. The requests are transformed into XML format and sent to the *Learning Service Registry* component for preliminary search and identify a list of candidate services. According to service URIs (Universal Resource Identifiers) available in the registry, the service requestor is directed to the corresponding *Learning Service Provider* for advanced search. Appropriate learning services are retrieved by matching the requests.

Learning Service Provider: A learning service provider, e.g., universities, schools, departments, and individual content authors, is an owner of learning services. These services with the tagged metadata are normally stored in their repositories. Instances of the learning object metamodel are used to manage learning services in each subject field. As a whole, a semantic representation represents concepts and relationships of a multidisciplinary knowledge domain. After preliminary search in the *Learning Service Registry* component, advanced search is undertaken to satisfy the requests by identifying an appropriate subject in the knowledge domain, searching learning services within the subject field and checking metadata of learning services for retrieval.

Learning Service Registry: A learning service registry provides a mechanism to systematically present and manage learning service providers and their learning services in a standard manner. Key metadata of learning services are registered for a preliminary search of services in the registry followed by the advanced search in the *Learning Service Provider* component.

6.2 Using UDDI for Management of Learning Services and Service Providers

UDDI in a *Learning Service Registry* captures some specific elements of the metadata tagging to the learning objects, e.g., `General` and `Classification` category. Build these elements in the UDDI will optimise the search of learning services for relevancy and suitability. Two major data structures—*businessEntity* [17] and *businessService* [17] in UDDI can be used to construct the specific elements of the metadata for registering the services.

The *businessEntity* structure contains comprehensive information of a learning service provider. Relevant metadata of learning services cover part of the elements in the structure—*Name* and *Contacts* in UDDI capture the value of `Lifecycle` in `General` category when the `role` attribute of `Contribute` is specified as `Content Provider`.

Figure 15 shows an instance of the *businessEntity* structure which describes a learning service provider—The University of Reading with a *businessKey* property uniquely identified in a registry. Simple textual information about the provider is given by its *name—The University of Reading*. Detailed contact information of the service provider is specified in *Contacts*. Short business *description,* such as *The University of Reading is a top rated* *research institution*, indicates the quality and educational level of the provider. *discoveryURLs* lists URLs that point to Web addressable discovery documents of the university, e.g., *http://www.reading.ac.uk*. The *identifierBag* contains a list of identifiers, each of which is valid in its own identifier system. For example, The University of Reading is uniquely identified by a nine-digit sequence—*212522689* in the system of D-U-N-S Number [17]. The *categoryBag* contains a list of business categories, each of which describes a specific business aspect of the provider. For example, The University of Reading is classified in the category of *Colleges, Universities, and Professional Schools* by NTIS [17]. A provider can be digitally signed for learning service authentication in *Signature* by holding a unique signature key.

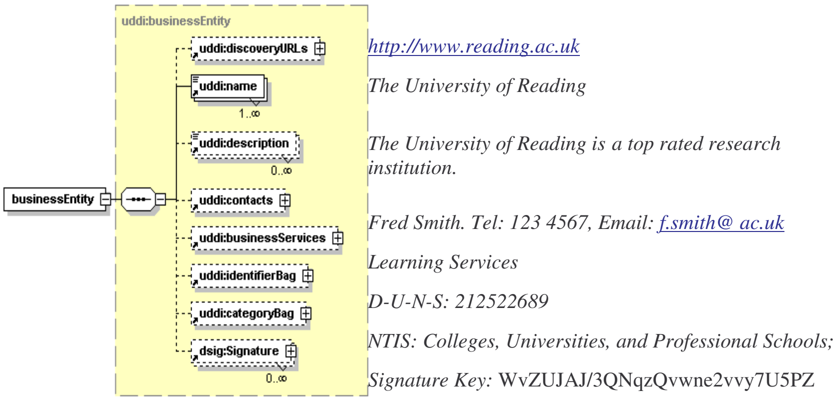

Figure 15. A Learning Content Provider Registered by *businessEntity*

A *businessService* in Figure 16 allows a learning service, LO_{ADUML} of its provider to be technically defined based on key information of its metadata. The `Description` in `General` category of metadata forms the *description* of the service. *bindingTemplates*, which contains the value of `Identifier` metadata provides technical information to invoke the service, typically a URL (*http://www.rdg.ac.uk/ug/courses/132.html*) and a brief description to indicate the applied protocol (*HTTP*) to the access point. The *CategoryBag* provides information in `Classification` category, such as *Undergraduate Programs* classified by UNSPSC system. The service can be signed in *Signature* by holding a unique signature key.

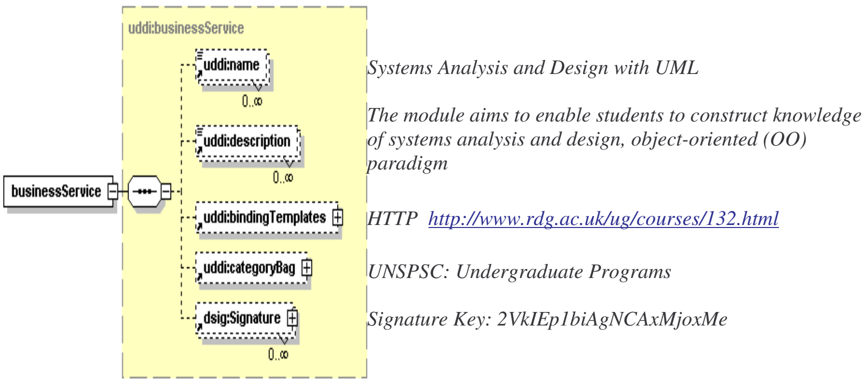

Figure 16. A Learning Service Registered by *BusinessService*

Figure 17 shows a sample interface of the underlining UDDI data structure. In 'Organization' area, the registry browser captures information about the service provider, e.g., The University of Reading. The 'Services' area presents learning services (e.g., LO_{ADUML}), which are categorised by UNSPSC classification system (*Undergraduate Programs* or *Postgraduate Programs*). The highlighted 'Service Bindings' gives the data in the *bindingTemplates* to show the access point and protocol of the learning service. Once submitted the registration, the registry automatically generates a unique *Id* number to identify The University of Reading as a learning service provider and a unique *Id* number for its learning services.

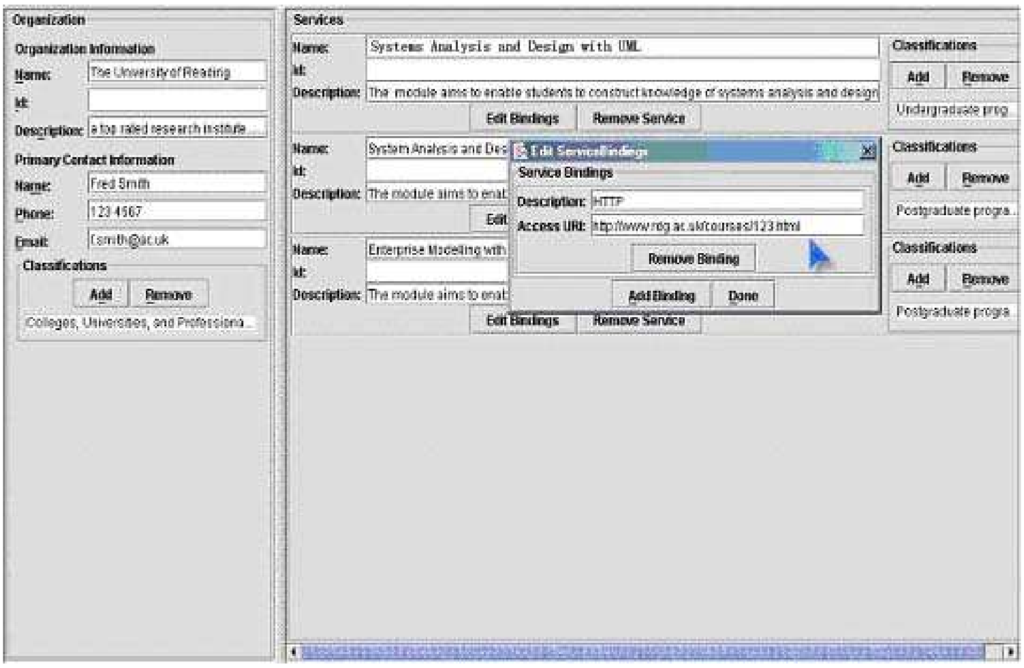

Figure 17. An Interface Presentation of a Learning Services Registry

A UDDI registry currently registers key metadata of learning services and services providers for preliminary search of learning services. It covers broad information of services and service providers from a business point of view. Other necessary set of metadata from educational perspectives can be added in by developing appropriate tModel entities, which in UDDI establish the existence of a variety of concepts or specifications along a number of dimensions.

7 Conclusions

An architecture of interoperability for learning services management are presented to enable learning services sharing and reuse in a heterogeneous environment. This aims ultimately to reinforce quality of instructional design and learning. Technical issues are discussed at different levels of interoperability. Special focus is on resolving syntactic interoperability. Schemas of learning services, e.g., learning objects, information objects and assessment objects are developed to capture information content in a generic manner. To facilitate services discovery from various repositories, the standard of learning object metadata is adapted in our practice by designing an application profile of learning objects. A model of e-learning services provision and a service management mechanism are presented by integrating the design of learning services, the Web services technology, and the best technical practices in the research community. Experiments through prototyping and testing have shown positive promises of the architecture.

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