Supporting Adaptive Learning Interactions with Ontologies

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ABSTRACT

The concept of adaptive technologies is increasingly prevalent in many areas, particularly in learning. In this context we require quick and robust approaches for developing adaptive learning environments. In order to construct such environments, we need to enable reusability of learning contents according to the needs of learners, which is one of the challenges for current learning technologies. In this paper we show how an ontology-based approach can help us to reuse the same learning contents for different purposes.

Categories and Subject Descriptors

H.3.4 [**Systems and Software**]: Question-answering (fact retrieval) systems; H.3.4 [**Systems and Software**]: Semantic Web; I.2.4 [**Knowledge Representation Formalisms and Methods**]: Ontologies; K.3.1 [**Computer Uses in Education**] Computer-assisted instruction (CAI)

General Terms

Management, Performance, Design, Reliability, Experimentation

Keywords

Adaptive learning environment, Learning management systems, Content-level adaptation, Learning objects, Semantic Web, Ontology, Domain model.

1. INTRODUCTION

The knowledge age we live in demands continuous learning support in accordance with the needs of learners. Current Learning Management Systems (LMS) have limited adaptive functionality, and are used to deliver the same sets of educational resources and tools to everyone, ignoring personalization aspects like differences in knowledge level, learning style, motivation and so on [1].

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However, according to recent studies, adaptive learning systems [2] (ALS) have an added advantage over non-adaptive systems by offering individualised support to learners [3]. Systems that support adaptive learning [4] give immediate responses according to the situation of the learners' progress during learning activities. They are considered particularly suited to well explored and structured content and can add value in a number of contexts; the acquisition of basic knowledge, the acquisition of technical details that are too cumbersome to cover in lectures or classes, adaptive testing of basic knowledge and language skills [5].

The classification of ALS is based on two levels of adaptation: Content-level adaptation and link-level adaptation [6]. In this paper, we discuss only content-level adaptation, which consists of selecting different information such as different text, images, videos, animation etc. depending on the learners' needs [7][8]. There are several possible techniques for content level adaptation including content hiding, additional explanation, specific media type filtering, specific item filtering, and different web page versions for different student learning styles [9], but they capture only limited information about learners and are not rich enough in supporting reuse of learning objects (LOs) for different purposes.

An LO is defined as "any entity, digital or non-digital, which can be used, reused or referenced during technology supported learning" [10]. Current learning standards and specifications including IEEE LOM (Learning object Metadata), IMS-LD (Instructional Management Systems Learning Design), IMS LIP (Learner Information Package), and IEEE PAPI (Personal and Private Information) are insufficient to provide information for dynamic learning activities in an adaptive learning environment [11][12]. However, it is possible to reuse learning objects and repurpose them dynamically by using an ontology-based design approach [13][14].

Ontology-based design approaches have gained interest as a technology in learning environments because they appear promising for improving information retrieval, by adding an intelligent layer based on semantic representations of the domain, the activities or pedagogical models [15]. An ontology is referred to as "an explicit specification of a conceptualisation" [16], an abstract and simplified vision of the world to be represented. It provides the vocabulary for referring to the terms in a particular domain. It also relates to some logical statements that describe what the terms are, and how they are classified, as well as some rules for combining terms and relations to define extensions to the vocabulary [17].

In this paper, we introduce an example domain ontology. This example shows how the same content can be reused for different purposes according to the needs of learners. Therefore, we are assuming that the reusability of the learning contents can provide dynamic learning activities during an adaptive learning process.

The rest of the paper is organized as follows. Section 2 presents some aspects regarding adaptation and ALS. Classification of ALS is discussed in section 3 while section 4 is concerned with LO reusability and our ontology-based approach. In section 5, we outline our domain ontology with its content level adaptation capabilities. Related work is described in section 6. Finally, in section 7, we draw some conclusions and point toward future research.

2. ADAPTATION AND ALS

Current LMS such as Blackboard[1], Moodle[2] and Dokeos[3] are used to deliver learning contents; however, they usually have limited adaptive functionality or do not offer personalized services, and learners are being given access to the same set of educational resources and tools, ignoring personalization aspects like: differences in knowledge level, motivation, interests and learning goals [1]. However, for technology enhanced learning, it is a major challenge to develop a learning environment that effectively enables each learner to get individualised support in filling ever-changing skills and competence gaps; i.e. to create an environment for personalised adaptive learning [18].

Some more experimental learning technologies are making it possible to provide immediate feedback to learners during learning activities performed in technology supported learning environments. An essential part of these technologies is to give responses according to the situation of the learners' progress during learning activities. This response is referred to as *adaptive learning* [4] and the systems are known as adaptive learning systems (ALS) [2]. ALS has two features (a) diversity – learning material may cater for some individual learners but may not suit others; (b) interactivity – in many circumstances, learners do individual learning via web-based learning systems, thus the on-demand assistance must be developed to act as a mentor much like teachers in the traditional classroom [19].

ALS uses what is known about an individual learner and dynamically alters the flow or content of learner activities. According to Edmond (1981) (cited in [9]), adaptation can take place in three forms:

- Adapted Systems provide adaptation in limited ways as they are customized according to a specific learner profile at design time only.
- Adaptable Systems allow learners to create their own profiles manually in order to specify preferences and needs. A profile can only be modified by the intervention of the learner.
- Adaptive Systems adapt themselves, based on continuous observation of learner preferences and needs. The profile of the learner is dynamically updated by the system, after tracking and analysing learner behaviour during learning processes.

A recent study was conducted to gather personalization and adaptation needs among corporate learners and training providers of six different European countries. According to that study, ALSs have an advantage over non-adaptive systems by offering individual treatment of learners. Moreover, the most salient features of adaptation include learning goal/task, learner knowledge, learning style, language, user role, platform, motivation and learner qualification [3]. ALSs can provide individualised teaching and learning support in a level of detail that cannot be covered adequately in a class or lecture. They are considered particularly suited to well explored and structured content and can add value in an academic context [5].

3. CLASSIFICATION OF ALS

The nature of the information that is modelled in ALSs is based on learner characteristics such as goals, tasks, knowledge, background, experience, preferences, interests, personality traits and environment including location, platform and bandwidth [20]. This is referred to as the learning context. In a broader sense, it is defined as "the situation under which a learning activity happens and this situation includes the learner and his/her surrounding environment" [21]. The classification of ALS is based on [6]:

- Adaptive presentation (content level adaptation)
- Adaptive navigation support (link level adaptation)
- Adaptive content selection (content level adaptation)

In this paper, we are discussing only content level adaptation. Content level adaptation focuses mainly on improving local navigation for a user and orientation in the currently presented page or fragments. It consists of selecting different information such as different text, images, videos, animation etc. depending on the different level of details required by learners [7][8]. For example, an adaptive web application provides an expert in a certain domain with more information than a novice or it can switch between different media types according to different user preferences or learning styles.

There are several possible techniques like content hiding (uses an 'is visible' attribute, associated with properties and conditions involving the special 'show' and 'hide' elements), additional explanation, specific media type filtering (e.g. no video or no audio), specific item filtering (e.g. no definitions, no examples etc.), and different web page versions for different student learning styles [9]. None of these techniques is rich enough to provide dynamic learning activities in order to facilitate reusing of learning objects. However, it is possible to reuse learning objects and repurpose them on-the-fly by using an ontology-based approach [13] [14].

1 http://www.blackboard.com/
2 http://moodle.org/
3 http://www.dokeos.com/

4. LO REUSABILITY

An important component of a LMS is the learning object (LO) that encapsulates various goals and contents. The main concern of an LO is to reuse and repurpose it in accordance with different requirements. In many cases, a paragraph, a sentence or illustration from a document is re-used by copy and paste into new and different documents.

Current learning standards and specifications include IEEE LOM, which gives information about the contents or the format of the learning object, and IMS-LD, which focuses on activities. Neither approach captures sufficient information for personalization of the learning process, which requires an awareness of context [11]. For example, even though the IEEE LOM metadata standard defines over 80 different metadata elements to be used when annotating LOs, only a couple of them are relevant for personalization purposes. Likewise, IMS LIP and IEEE PAPI are more generic, therefore they are not conceptually extensible, and most of these standards are not configured to represent dynamic learner information which can be an important element for any adaptive learning environment [12].

Being aware of the shortcomings of the present learning standards and specifications, we therefore opted for an ontology-based design approach for adaptive learning environments. Ontology-based design has gained interest as a technology in learning environments because it appears to promise to improve information retrieval, by adding an intelligent layer based on semantic representations of the domain, the activities or pedagogical models [15]. Aside from their potential for searching, ontologies have been used for supporting visualization and access. Another use of ontologies is to help define standards and strategies in a learning domain. Learning standards are being developed to ensure that learning resources can be networked and shared among learning communities and across different learning applications [22].

The new age of the Internet is the Internet of meanings, i.e. the Semantic Web [23]. It has a vision for making the contents of the web understandable to machines. This new generation of the web has the ability to enhance information retrieval, the reuse, sharing and exchange of resources through the internet/intranet according to the needs of users [24]. The Semantic Web provides ontology notations and techniques, based on the ontology language OWL (Web ontology language) that is based on RDF (Resource Description Framework) and XML (the eXtensible Mark-up Language). Schema languages, such as XML Schema or RDF Schema, are the tools to introduce the vocabulary into an ontological framework [25]. OWL is an ontology language that extends RDF. The RDF is an XML-based language which describes resources like images, files or concepts available via the Web. The RDF model is called a Triple because it has three parts; subject, predicate and object. The subject and object are resources while predicate indicates their relation. Semantic web documents must be represented as RDF which defines common data of specific domains based on an ontology which represents data relations [26].

5. FIRST-AID DOMAIN ONTOLOGY

This paper introduces an example domain ontology which may be integrated with learner and context models for developing an adaptive learning environment. Here, we are presenting first-aid as an example for our domain model, as depicted in Figure 1, and show how it can be reused in different ways to share knowledge. The domain model is used to provide a conceptualization of the domain-dependent knowledge with which the learner is concerned during the learning process [27].

First-aid is a common learning domain and a knowledge of first-aid can be used in emergency situations like heart attacks, bleeding, choking, poisoning, spinal injuries, scalds and burns etc. before professional medical help can be provided. A good learner can save lives just by applying knowledge of this domain in a particular type of situation. Therefore, we chose this commonly understood and practical domain for our adaptive learning environment example.

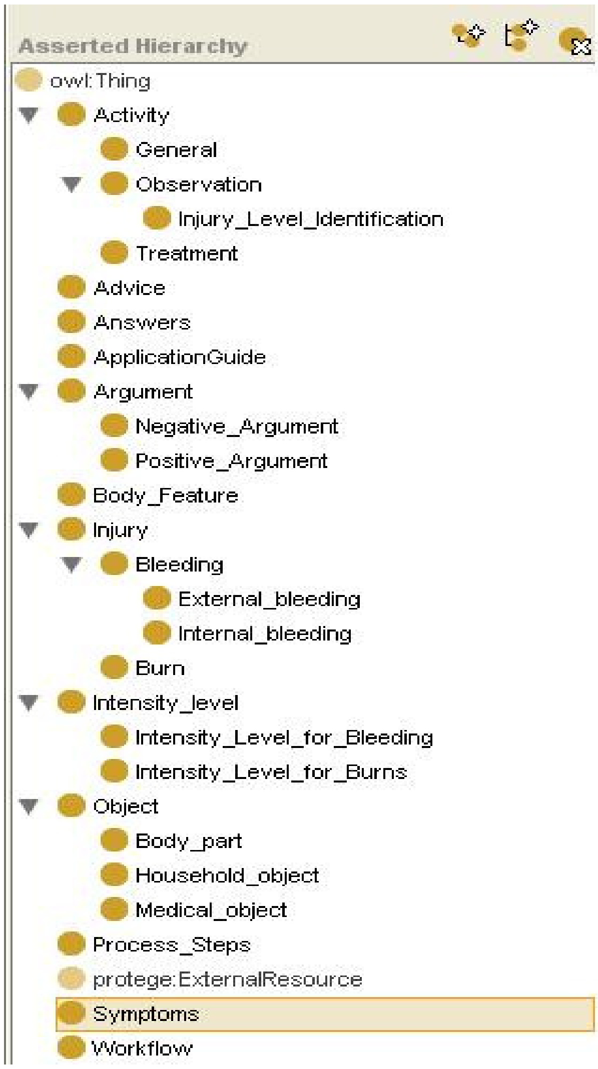


Figure 1. First Aid Ontology – Domain Model

5.1 Ontology Structure

This ontology covers a small sample of only two important aspects of first-aid knowledge domain; Bleeding and Burning. However, it can be considered as the representation of the whole domain. The structure of this domain ontology is based on several important classes. Classes are defined using an 'owl:class' element as shown in the example below. The 'Activity' class defines the sub activities ('General', 'Observation', and 'Treatment'). The 'Injury' class categorises a number of injuries like 'Bleeding', 'Burning' and their sub categories (e.g. in the example below 'External_bleeding' is a subclass of 'Bleeding').

```
<owl:Class rdf:ID="External_bleeding">
<rdfs:subClassOf>
<owl:Class rdf:ID="Bleeding"/>
</rdfs:subClassOf>
</owl:Class>
```

Definitions of each category and their relationships with other classes are specified. The 'Advice' class records all types of advice that can be relevant to any activity or injury. The 'Symptoms' class identifies the cause of the injury and requirements of the application to a particular injury. The 'Intensity Level' class is used to describe the severity of the injury e.g. 'First Degree Burn' or 'Severe External Bleeding'. The 'Object' class is classified into three types: 'Body part', 'Household objects' and 'Medical objects' such as 'cold water', 'cling film', 'adhesive plaster', 'hands' etc. Objects can be used while performing any activity for a particular injury.

Data type values are related to objects, known as data type properties [28], which can be defined at the design time of an ontology. In our example definition of bleeding, its default name is 'Bleeding' with the alternative name 'Haemorrhage'. These are specified in the 'Definition', 'Default_Label' and 'rdfs:label' (used for an alternative label) elements respectively.

```
<Bleeding
rdf:ID="Bleeding_Injury_represents_class">
<rdfs:label rdf:datatype=
"http://www.w3.org/2001/XMLSchema#string"
 >Haemorrhage</rdfs:label>
        .
        .
        .
        .
<Definition xml:lang="en"
>is the escape of blood from capillaries,
veins, and arteries. It has two major
types:</Definition>
<Default_Label rdf:datatype=
"http://www.w3.org/2001/XMLSchema#string"
>Bleeding</Default_Label>
</Bleeding>>
```

Object properties [28] relate objects (instances of classes, that is, interesting elements of the domain of discourse) to other objects. These properties are defined through different functions to express an ontology. We have used some functions like 'requires_action' and 'has_advice' that are used to explain a particular treatment for a specific injury, e.g. 'Direct Pressure' is an activity (Treatment) that gives advice before any action is taken. The following part of an ontology shows such object properties being defined for our domain.

```
<has_advice>
<Advice
rdf:ID="Do_not_apply_pressure_neck">
<Definition xml:lang="en"
>Do not apply direct pressure to the neck
(carotid)</Definition>
<is_relevant_for
rdf:resource="#Direct_Pressure"/>
</Advice>
</has_advice>
```

5.2 Adaptive Learning Content

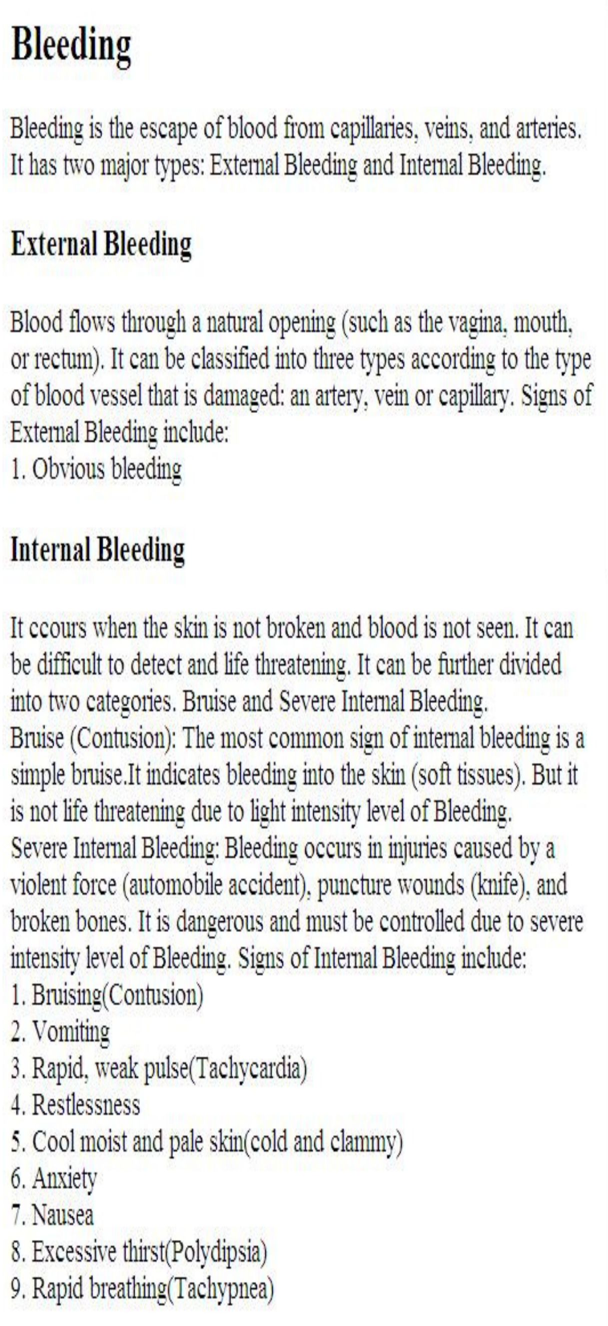
Learning content needs to meet the expectations and requirements of the learners. Adapting content to individuals and groups of learners before the content is presented is of major importance. In our example, we show how the first-aid domain ontology can be represented in two different ways, i.e. as a tutorial (in plain text) and as multiple choice questions (MCQs) as depicted in Figures 2 and 3 respectively. The former representation can be used for describing the knowledge of the first-aid domain to learners while the latter representation can provide an opportunity to evaluate learning performance.

The information for these representations is extracted through the data type and object properties defined in our domain ontology. In this particular example, an extract from the tutorial covers the main topic of 'Bleeding'. It represents sub-types of bleeding and their symptoms. The 'Default_Label' and 'Definition' are used as data type properties whereas 'Is_cause_of' and 'has_caused' are used in order to explain the relationship between the Injury and Symptoms classes as object properties.

```
<owl:ObjectProperty
rdf:about="#has_caused">
<owl:inverseOf
rdf:resource="#Is_cause_of"/>
<rdf:type
rdf:resource="http://www.w3.org/2002/07/owl
#InverseFunctionalProperty"/>
<rdfs:comment
rdf:datatype="http://www.w3.org/2001/XMLSch
ema#string"
>Signs of</rdfs:comment>
<rdfs:domain rdf:resource="#Injury"/>
<rdfs:range rdf:resource="#Symptoms"/>
<rdfs:label
rdf:datatype="http://www.w3.org/2001/XMLSch
ema#string"
>include :</rdfs:label>
</owl:ObjectProperty>
```

The ontology excerpt above shows the comment 'Signs of'. Figure 2 shows how this comment is reused; it is used in both

'Signs of external bleeding' and 'Signs of internal bleeding'. Symptoms are also displayed according to the bleeding sub-type as shown in Figure 2. We have defined a 'Signs of' injury (domain) and its symptoms (range) which can be reused with other injuries as well. Moreover, the whole tutorial is represented in such a way that each resource has a relationship with other resources by using their data type and object properties.



Bleeding

Bleeding is the escape of blood from capillaries, veins, and arteries. It has two major types: External Bleeding and Internal Bleeding.

External Bleeding

Blood flows through a natural opening (such as the vagina, mouth, or rectum). It can be classified into three types according to the type of blood vessel that is damaged: an artery, vein or capillary. Signs of External Bleeding include:
1. Obvious bleeding

Internal Bleeding

It ccours when the skin is not broken and blood is not seen. It can be difficult to detect and life threatening. It can be further divided into two categories. Bruise and Severe Internal Bleeding.
Bruise (Contusion): The most common sign of internal bleeding is a simple bruise.It indicates bleeding into the skin (soft tissues). But it is not life threatening due to light intensity level of Bleeding.
Severe Internal Bleeding: Bleeding occurs in injuries caused by a violent force (automobile accident), puncture wounds (knife), and broken bones. It is dangerous and must be controlled due to severe intensity level of Bleeding. Signs of Internal Bleeding include:
1. Bruising(Contusion)
2. Vomiting
3. Rapid, weak pulse(Tachycardia)
4. Restlessness
5. Cool moist and pale skin(cold and clammy)
6. Anxiety
7. Nausea
8. Excessive thirst(Polydipsia)
9. Rapid breathing(Tachypnea)

Figure. 2 An excerpt from the tutorial

The same information that is encapsulated in the first-aid ontology is also used to construct MCQs. For developing questions from the same ontology, we have defined several data types and object properties to express our ontology. In our example, we have used only the 'Default_Label' and 'rdfs:label' (used for alternative label) for defining questions as shown in Figure 3. These are therefore *label questions*, which enquire about the alternative name for a particular injury, symptom or treatment. These questions can be asked in order to test learning performance. A few label questions are used here to demonstrate how the same contents can be reused. In addition, alternative names of the same kind are grouped together as options (answers) for a specific question. For example, 'Dermal Injury', 'Full thickness Burn', 'Partial Thickness Burn' and 'Superficial Burn' all are related to burn degrees, so they should be included where alternative names for degrees of burning have been asked (as depicted in Figure 3).

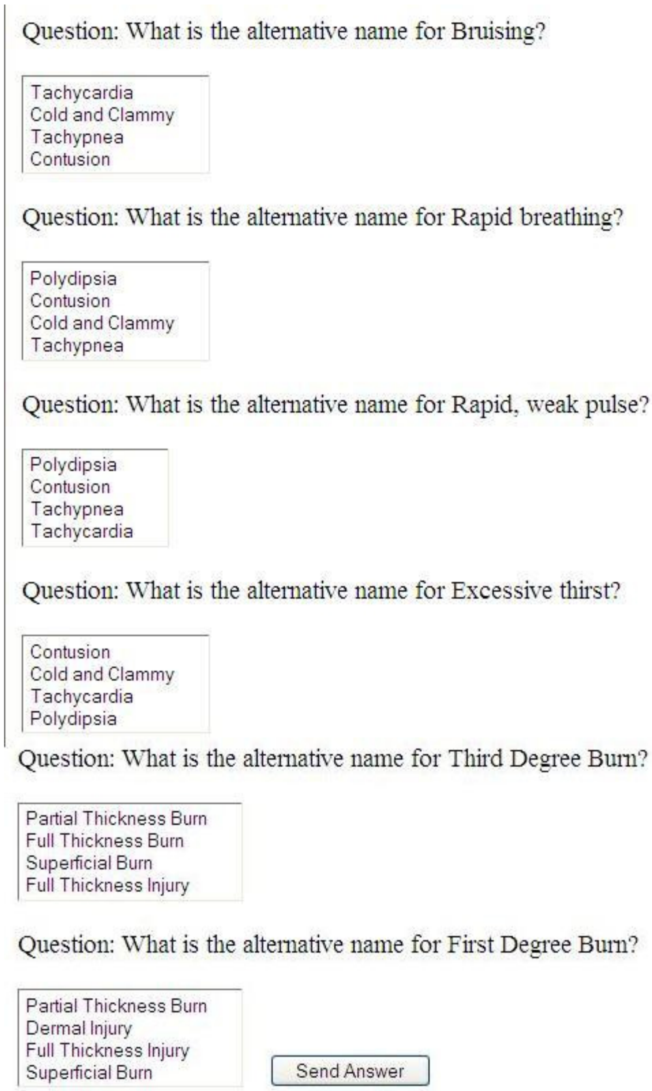


Figure. 3 Label Questions from domain ontology

The questions about these alternative names have been generated through our domain ontology. In part of the ontology we have defined the 'Burn' and 'Intensity_Level' classes with a relationship through the 'could_be_result_of' object property. These identify the intensity levels (degrees) of the burns. In our learning domain, four degrees of burns, namely first, second, third and fourth degrees are described. All these degrees have alternative names e.g. 'First degree burn' is also known as 'Superficial Burn'. This data forms the source for several of the questions in Figure 3. In the same way, other questions based on labels can be extracted from our domain ontology, whether symptom, treatment or class, as they should have a defined alternative name. The following example shows the label data for the symptom 'Excessive thirst' with the label 'Polydipsia' and the default label 'Excessive thirst'

```
<has_caused>
<Symptoms rdf:ID="Excessive_thirst">
<rdfs:label
rdf:datatype="http://www.w3.org/2001/XMLSch
ema#string"
>Polydipsia</rdfs:label>
<Default_Label xml:lang="en">Excessive
thirst</Default_Label>
<Is_cause_of
rdf:resource="#Internal_bleeding_represents
_class"/>
</Symptoms>
</has_caused>
```

In Figure 2, the symptom 'Excessive thirst' can be seen displayed as part of a tutorial by defining its default and alternative names. On the other hand, the same information is used to generate an MCQ in Figure 3.

In the MCQs in Figure 3, the default labels are used to generate the questions while alternative names are given as options for answers. The correct alternative name is included in the given options with three other alternative names. The most interesting thing about the other alternative names is that they belong to the same group. For example 'Excessive thirst' has three wrong answers ('Tachypnea', 'cold and clammy', 'Contusion'). All these are alternative names but they all are symptoms of internal bleeding. Therefore, options can be given to the learners which are of the same kind. In addition, all these options are generated through a random function so the system randomly selects the incorrect options for each given question from a pool of a similar group type. As a consequence, dynamic MCQs will be generated that may help learners to improve their knowledge.

This example shows that an ontology based approach can support adaptive learning contents. In our domain ontology, the same contents are reused in two different ways. However this example is limited to label questions. More work is still needed in order to explore further adaptability of learning contents in accordance with the needs of learners. Questions need to be presented to learners according to their knowledge level (beginner, intermediate or expert), learning styles and preferences. Furthermore, questions including arguments about any treatment, relevant advice for any injury, steps taken during the first-aid process and definitions of particular terms may be extracted from the same ontology in the future.

6. RELATED WORK

TANGRAM [13], an intelligent learning environment for the domain of intelligent Information systems, used an ontology based approach for automatic decomposition of LOs into reusable fragments and dynamic reassembly of such fragments into personalized learning content. It is implemented as a Web application and intended to be useful to both content authors and students. Functions of the system from the students' perspective include the provision of learning content adapted to a students' current level of knowledge of the domain concept of interest, personal preferences and their learning styles and also the provision of quick access to a particular type of content [13]. Being partially inspired by the work [13], our approach to content adaptability exhibits some common traits with TANGRAM.

In the APOSDLE [29] project, the system identifies missing competencies of learners and their learning needs. Moreover, it suggests appropriate learning resources according to the immediate work context of a learner. As in TANGRAM, in the APOSDLE project, the focus is also on reuse of content units of low granularity (e.g. a paragraph, an image, a page). The approach for content preparation for reuse is also similar: existing documents are segmented into smaller fragments and semantically annotated with concepts from the domain ontology so it is possible to get adaptive learning content according to the requirements of learners.

The ontology model [30] is developed as a part of the research project conducted by the Department of Information Systems at the Corvinus University of Budapest, which aims at introducing an interface, which can develop a customised qualification program, based on individual learning traits. The model itself consists of two modules including the Test module and the e-Learning environment. The main idea behind adaptive testing is that the test should tailor itself to the estimated ability level of test takers and take into account how each test taker has answered previous questions. We have a similar approach in our ontology model. Our domain ontology does not currently support taking account of previously answered questions. However, questions and options (answers) are generated dynamically through an ontology and the presentation of the questions can be adapted according to the knowledge levels of the learners.

In the competency management domain, an ontology based prototype was developed [31] which integrates competency management with e-learning and other human resource factors such as succession, career planning, training needs analysis and organization planning, in order to provide an ontology based competency management system. All of the above mentioned learning applications use ontologies in order to achieve a dynamic learning process and reusability of learning contents for different purposes in a particular domain.

7. CONCLUSION & FUTURE WORK

In this paper, we have discussed a need to explore an ontology based approach for an adaptive learning environment that enables reusability of the contents for any domain. Such an environment requires a flexible underlying domain model that we provide in the form of a first-aid ontology. Specifically, we argue for adopting an ontology-based approach in providing learning contents adaptive to the specific needs of each individual learner. To evaluate the feasibility of the proposed approach, we have developed a web-based learning environment for first-aid learners. Reusability of the contents may guide learners during the learning process and also may be helpful for constructing knowledge domains within an LMS

The work presented in this paper is still in early stages. We are currently working on the design of the first-aid ontology, learner ontology and context ontology. We may leverage these ontologies to develop an adaptive and personalized learning environment. Further, our plans include the enrichment of the first-aid ontology with the extraction of different questions according to the knowledge level of a learner In addition, learning styles or personality traits of learners may be taken into account while representing domain knowledge to them. Learner ontologies can play a vital role in defining learner characteristics which may be mapped with domain ontologies to provide personalized support during a learning process. Moreover, adaptation of the learner information may be distributed among different contexts with the help of context ontologies for developing a flexible learning environment between current and future learning technologies. That might help us to understand how ontology-based systems can possess the necessary flexibility to respond to dynamic learner activities in adaptive learning environments.

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