KNOWLEDGE REPRESENTATION FRAMEWORK FOR CURRICULUM DEVELOPMENT

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Abstract: This paper presents the formal representation of knowledge used in curriculum development process. Four curriculum components are represented separately: learning objectives, learning experiences, the organization of learning experiences and evaluation of learning outcomes. Learning objectives are formally represented using ontologies. Learning experiences consist of learning objects and achievements assessment instruments (tests) and they are specified using IMS Content Packaging standard. Learning experiences are mapped to the learning objectives ontology using XML. For describing instructional design, we proposed a special-purpose language implemented using XML notation. The achievement of a learning objective is assessed using test items linked to this particular objective. Such an approach allows more flexible management of the curriculum as a whole and easier modification of the particular components than in classical approach.

1 INTRODUCTION

For the proper management of a curriculum development process, a formal specification of all curriculum components is essential. This formal representation should be used for automation of the curriculum creation process. Besides, it enables automation of curriculum. We start by analyzing Tyler's rationale for curriculum development. Tyler's rationale states that in any educational setting, when developing curriculum, four fundamental questions must be considered (Tyler, 1949):

1. What educational purposes should the school seek to attain?
2. What educational experiences can be provided that are likely to attain these purposes?
3. How can educational experiences be effectively organized?
4. How can we determine whether these purposes are being attained?

These questions can be reformulated in a more familiar way as forming the process of curriculum and instruction development consisting of: the selection of learning objectives, the selection of learning experiences, the organization of learning experiences, and the evaluation of learning outcomes (Tyrell, 1974).

In this paper it is shown how the knowledge used in the steps of the process of curriculum and instruction development can be represented. The relationships among the steps are stressed as well. Each step is represented as an independent component, because such approach is more flexible and it provides easier modification of the curriculum.

2 LEARNING OBJECTIVES

The formulation, classification and organization of learning objectives play very important roles in Tyler's rationale since all other steps proceed from them. In this paper, a learning objective is understood as "an explicit formulation of the way in which students are expected to be changed by the educational process", and these changes can be represented using taxonomies (Bloom, Engelhart, Furst, Hill and Krathwohl 1956).

When the content of learning objectives is represented, the number of the taxonomies to be represented equals to the number of courses. The explicit representation of the content facilitates

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establishing the relationships among the learning objectives.

When representing learning objectives, students' behaviours involved in these objectives should also somehow be represented. For that purpose Bloom's taxonomy, taxonomy of students' behaviours which represent the expected learning outcomes had been designed (Bloom et al., 1956).

Three levels of specificity of learning objectives are identified in (Anderson, Krathwohl, Airasian, Cruikshank, Mayer, Pintrich, Raths and Wittrock, 2001.): *global*, *educational*, and *instructional*.

Although ontologies have wider range of use, they are natural tool for representing taxonomies. Therefore we have decided to use OWL full to represent learning objectives. Learning objectives ontology conjoins domain knowledge taxonomy, Bloom's taxonomy, and learning objective specificity taxonomy. In Figure 1 an example of representation of a concrete learning objective is shown.

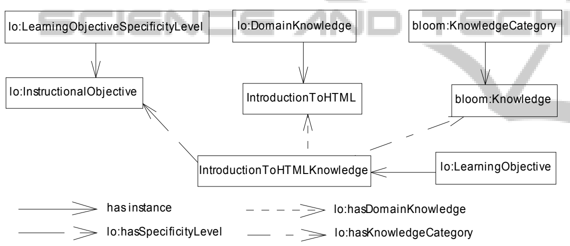

Figure 1: Representation of a learning objective IntroductionToHTMLKnowledge.

While learning, a student must achieve less complex learning objectives before he or she can proceed to more complex ones. Accordingly, the feasible (consistent) combinations of the learning objectives have to be established. Knowledge space theory facilitates representing feasible individual knowledge structures with respect to the set of problems that a student should be able to solve (Doignon and Falmagne, 1999). As achieving a learning objective means being able to solve a problem, the set of problems can be mapped to the set of learning objectives (Segedinac, Savic and Slivka. 2010).

When representing learning objectives, we confine to learning spaces with the quasi ordinal set of learning states. These knowledge spaces can be represented using *surmise* relation introduced in the set of learning objectives. Learning objective q_1 *surmises* learning objective q_2 if, from knowing that a student has achieved q_1 we can infer that he or she has achieved q_2 (Doignon and Falmagne, 1999). Organizing learning objectives in a knowledge space facilitates knowledge assessment and allows chaining of learning objectives.

According to Bloom's taxonomy (Bloom et al, 1956), when learning objectives refer to the same domain knowledge, the objectives which require lower cognitive processes are prerequisites for those which require higher cognitive processes. This rule was built in our model using SWRL rules. Besides that, user can specify *surmise* relation among learning objectives freely.

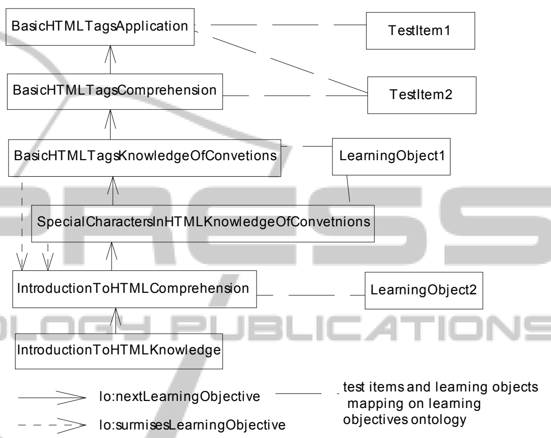

Figure 2: The mapping of learning objects and test items to learning objectives chain with surmise relation.

After knowledge space was built on the set of learning objectives, a chain of learning objectives should be defined. For that purpose we introduced relation *next* (a relation of total ordering) in the set of learning objectives, forming a chain of learning objectives. This relation allows us to suggest the order of achieving learning objectives and is useful when organizing learning experiences. Relation *next* was introduced with respect to *surmise* relation, specifying new SWRL rules. In Figure 2, an example of learning objective chain with *surmise* relation and learning objects and corresponding test items is presented.

3 LEARNING EXPERIENCES

A student gets most of the learning experiences by consuming specific learning resources. Thus, our component for representing learning experience should formally describe learning resources. For this purpose, we suggest IMS Content Packaging specification, which is globally accepted.

Although we define the learning objectives and learning material as separate components, there is still strong relationship between these components. Students use learning objects to achieve learning objectives and teachers use tests to evaluate students' knowledge. Thus, learning resource is always related to one or more learning objectives. To describe this relationship, we have created an intermediate component that defines mapping between learning resources and learning objectives. We use a particular XML document to define this mapping. The relationship between learning objectives and material is shown in Figure 2.

It can be noticed that in our approach ontology of learning objectives has a role to define relations among learning resources. Thus, the relation is not defined as a part of the resource, but it is implicitly defined through ontology. By this, it is easier to change relation between two resources, i.e. in order to change relation between two resources; one should only map the resource to another objective. Likewise, when adding a new resource, its relationships with other resources are indirectly defined by its learning objectives.

4 ORGANIZATION OF LEARNING EXPERIENCES

In the previous chapter we assumed that learning experience is closely related to a specific learning resource. Thus, the organization of learning experiences is actually defined by two components - selecting and organizing learning resources. These two components define instructional design used in a course. Although there are numerous different instructional strategies (Ryder, 2010), there is no formal language aimed at specifying instructional design. Formal specification of instructional design should enable computer-aided reasoning about instructional design. For that purpose, we have created an XML-based language formally describing instructional design used in the course. This language should provide ability for a teacher to define the order of learning activities and criterion for selecting learning resources (number of resources, their type, and priority). For these reasons, our instructional design language defines the path through the learning objectives (objectives are represented as nodes in the ontology, see Figure 2). For each objective, the language specifies an ordered subset of the resources mapped to the objective.

In Figure 3. the UML model of our proposal for instructional design specification is presented.

Root element in the model is *instructional design* element representing the course. *Structure element* is a generic learning element in organization. There are two different types of elements – *sequence* and *learning object*. *Sequence* is a chain of other elements. *Learning object* is a unit of learning on the lowest hierarchical level. It actually represents a concrete learning resource. For each *sequence* we can define a specific strategy for selecting learning resources. This strategy is defined in *selection rule* element. *Selection rule* aggregates two lists of *Object selection* elements. First list contains objects that are included in the course. The second one is for excluded objects. *Object selection* element specifies learning objects for including or excluding. For included learning objects, we set an integer value called priority, which defines the order of learning objects in the sequence.

Besides the course structure, sometimes it is necessary to define relationships among learning elements. For example, in mastery learning, a student can't proceed to the next learning objective until he or she has completed the previous one. So, we need to define the relationship between two learning objectives. These relationships are specified using *element relation* element. This element has references to the source and destination learning elements, respectively.

Condition specifies when two elements are in the relationship. If the condition is satisfied, a specific action (defined in the *then action* element) is done. Otherwise, an action defined in the *else action* element is executed.

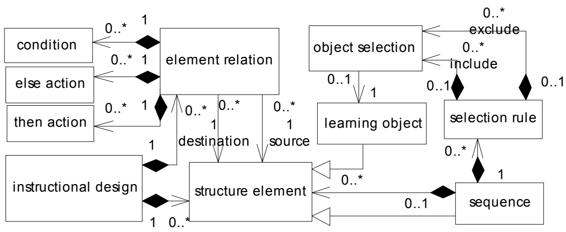

Figure 3: The UML 4model of proposed instructional design specification.

On the basis of the described UML model, we created an XML schema. Listing 1 presents a part of an XML document, created according to the schema. The document formally describes instructional design used in the "Web programming" course held at Faculty of Technical Sciences Novi Sad in 2009.

5 EVALUATION OF LEARNING OUTCOMES

The precise identification of the set of achieved learning objectives plays the key role in successive learning, because it leads further learning process (Mager, 1984).

Knowledge space formed on the set of learning objectives proposed in this paper allows us to use techniques enabling the explicit specification of achieved learning objectives. Each test item is mapped to specific learning objective(s) and multiple test items can be mapped to the same learning objective (Figure 2). These techniques explicitly identify the set of learning objectives that student has achieved, and can be used in interactive assessment (Degreef, Doignon, Ducamp and Falmagne, 1986; Falmagne and Doignon, 1988), as well as in classical educational settings (Segedinac et. al. 2010).

```
<instructional-design root =”course”>
 <uol-structure>
  <sequence element = "go">
   <sequence element = "io” >
   <sequence element = "learning-object">
    <selection-rule>
     <include type="ec" priority="1"/>
     <include type="exmp" priority="2"/>
     <include type="all" priority="3"/>
     <exclude type="exercise"/>
    </selection-rule>
    </sequence>
   </sequence>
   <learning-object type="exercise"/>
  </sequence>
  <sequence element="learning-object">
   <selection-rule>
   <include type="project" priority="1"/>
   </selection-rule>
  </sequence>
  <learning-object label = "final_test"/>
 </uol-structure>
```

Listing 1: Instructional design example.

6 CONCLUSIONS

In this paper a formal knowledge representation model for curriculum development process automation is proposed. The model consists of four components: learning objectives, learning experiences, the organization of learning experiences, and the evaluation of learning outcomes. Classical approach to modelling curriculum development process often uses the monolithic representation of the process resulting in situation where small changes cause alteration of the whole structure. In our approach, each component is modelled separately which allows managing curriculum in a more flexible manner and altering components more easily than in a classical approach. Future works will include extending one of the existing open-source e-learning systems with proposed curriculum development module. Such an e-learning system would allow further pedagogical research related to optimization and evaluation of the educational process.

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