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The Learning-Resource-Type is Dead, Long Live the Learning-Resource-Type!

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Abstract

Re-use is a major instructional and economic motivation for the wide propagation of the learning objects paradigm. Re-use, especially automatic re-use, requires metadata, and although IEEE LOM and similar standards provide an abundance of properties, they fail to represent relevant information about learning object, namely the instructional purpose of the object. The property “learning-resource-type” partly tackles the problem, but mixes several kinds of purposes and omits others. In this paper, I will describe an ontology of instructional objects that synthesizes a number of pedagogical theories and knowledge representations and provides an exhaustive description of the purpose of a learning object thanks to which instructional re-use becomes easier possible.

1. Motivation

Authoring good learning materials is expensive in terms of time and money. A driving force behind the advent of learning objects (LO) is the hope of re-using learning materials, possibly (hopefully) authored by another person. Currently, research investigates the automatic, machine-driven usage of LOs, for instance for automatically composing a lesson out of several learning objects [25,11].

However, one should not forget that the foremost purpose of LOs is learning. Objects and courses should serve to adequately present the content to the user and to ease the act of learning is much as possible.

But today, to search, especially by a machine, for adequate learning objects is not really possible. Search requires metadata, and the most prominent learning object metadata standard, IEEE LOM [8] fails to represent crucial information relevant from a instructional point of view.

In this paper, I present an ontology of instructional objects that synthesizes a number of pedagogical theories and knowledge representations, and provides an exhaustive description of the purpose of a LO thanks to which instructional re-use becomes easier possible. The first section of this article describes in detail the theoretical instructional background of the ontology and the shortcomings of IEEE LOM. Section 3, the main part of the paper details the scope and elements of the ontology.

2. Instructional Background

1. Instructional Design

Instructional design provides guidelines for authoring learning materials that effectively and efficiently support the learner in achieving learning goals (see [20,21,24,4]). As an example, in [17] Merrill describes basic, domain independent principles of instruction: Provide the learner with a real-world problem; activate their relevant previous knowledge; show them what to do; let them do it by themselves; and encourage them to integrate the knowledge.

Instructional design is relevant for e-learning and needs to be supported from the beginning of the authoring process. It provides hints at what LOs should be presented, in which order, for which learning goals. A human teacher who wants to compose a course needs to be able to search for LOs that fulfill instructional tasks. But successful search is only possible if the searched-for data is represented; which is even more important in case the teacher is a machine. The next section shows that in the case of e-learning crucial information is only partly represented.

2. Shortcomings of Today's E-Learning Standards

Particularly relevant in the context of this article is the IEEE Learning Object Metadata standard (LOM, [8]). LOM's educational category partly allows a description of resources from an instructional perspective. Properties such as "difficulty" or "typical-learningtime" convey important information; however, in the context of instructional design, the "learning-resource-type" (LOM's property 5.3) is of particular interest.

Its possible values are *Exercise, Simulation, Questionnaire, Diagram, Figure, Graph, Index, Slide, Table, Narrative Text, Exam, Experiment, ProblemStatement, SelfAssesment*. The problem with these values is that they mix instructional and technical information. Whereas *Diagram, Figure, Graph, Slide* and *Table* describe the format of a resource, other values such as *Exercise, Simulation* and *Experiment* cover the instructional type. They represent different dimensions, hence should be separated. Furthermore, several instructional objects are not covered by LOM (e.g., *definition, example*). Similar arguments apply to alternative vocabularies of the LOM learning-resource-type (e.g., [6]).

This section motivated why the learning-resource-type "is dead". In the following section, I will make a proposition how "to revive" it, for a long and prosperous live.

3. An Ontology of Instructional Items

The goal of this work was to derive a pedagogically sound ontology of types of learning resources that allows for efficient reuse. The principal design goals were:

- Domain independence. The types should be independent of the domain that is being taught, i.e., they should characterize learning material about mathematics as well as literature.
- Pedagogical flexibility. The types should be independent of the instructional theory underlying the learning material, i.e., they should describe constructivist as well as more traditional didactic approaches.
- Completeness. The types should cover the range of learning materials as much as possible.
- Compatibility. Existing standards and e-learning knowledge representations should be mapped on the types of the ontology as easy as possible.
- Applicability. Authors should be able to understand and apply the ontology. LOM, for instance, is notorious for putting a heavy load on content developers.
- Efficiency in searching. Users should be able to narrow the search down quickly using terms that reflect what they need.
- Machine processability. The types (together with other metadata) should enable sophisticated machine applications to find learning objects without human intervention.

In order to provide an ontology that complies with these goals as much as possible, it was necessary to analyze a significant amount of sources. Here, sources ranged from text classification ([15]), over instructional design (e.g., [20,21,5,24,4,28,16]) to knowledge representations of structured texts [2,27,18] or implemented in e-learning systems (e.g., [26,12,23,19,14,3,9]).

Let me stress again that this ontology does not describe the content taught by the learning material, e.g., "addition of fractions". Instead, each class of the ontology stands for a particular instructional role a LO can play, for instance "An EXAMPLE for addition of fractions" or "An INTRODUCTION for addition of fractions".

The ontology was evaluated and adapted iteratively. The last evaluation was done within the European FP6-Project LeActiveMath[1], among others by the e-learning lab of Klett, the biggest publisher in the educational market in Germany.

1. Why an Ontology?

An ontology provides more information than a taxonomy (a hierarchy of terms). It allows representing different relationships between the terms and how they are composed of different terms. For instance, using the ontology of instructional objects, an author can specify that a LO is an example *for* another learning object.

Compared to LOM's resource-type which is a flat list, even a taxonomy has definite advantages. For instance, using the term hierarchy, a search engine can use the tree structure, e.g., if for a specific query no element was found, then better than returning no or a random result, the search can be widened to include siblings or parent nodes.

2. Description of the Ontology

In the following, I will describe the classes and properties of the ontology of instructional objects (shown in Figure 1). The ontology was implemented using Protégé ([7]) and is available as an OWL file[2].

Instructional Object. "Instructional object" is the root class of the ontology. Several properties are defined at this level: a unique identifier; "learning context", which describes the educational context of the typical target audience; and "field", which describes the field of the target audience. An additional slot includes Dublin Core Metadata. The property "analogous" indicates that an instructional object shares some aspects with another instructional object.

Concept. The class "concept" subsumes instructional objects that describe the central pieces of knowledge. Pure concepts are seldom found in learning materials. Most of the time, they come in the form of one of their specializations. Albeit concepts are not necessarily instruction-specific because they cover types of knowledge in general, they are included in the ontology because they are necessary for instruction. LOs often have the instructional function of presenting a concept. Concepts rarely stand alone, more often than not they depend on another concept. This is represented by the *depends-on* property which has its range the class "concept".

Fact. An instructional object that is a "fact" provides information based on real occurrences; it describes an event or something that holds without being a general rule. An example "Euclid lived from about 365 to 300 BC".

[1] http://www.leactivemath.org
[2] http://www.ags.uni-sb.de/~cullrich/oio/InstructionalObjects.owl

Definition. A "definition" is an instructional object that states the meaning of a word, phrase, or symbol. Often, it describes a set of conditions or circumstances that an entity must fulfill in order to count as an instance of a class. An example is "The middle ages describes the period of time that…".

Law. An instructional object that is a "law" describes a general principle between phenomena or expressions that has been proven to hold, or is based on consistent experience.

Law of Nature. A "law of nature" is a scientific generalization based on observation. A typical example is "Kepler's first law of planetary motion".

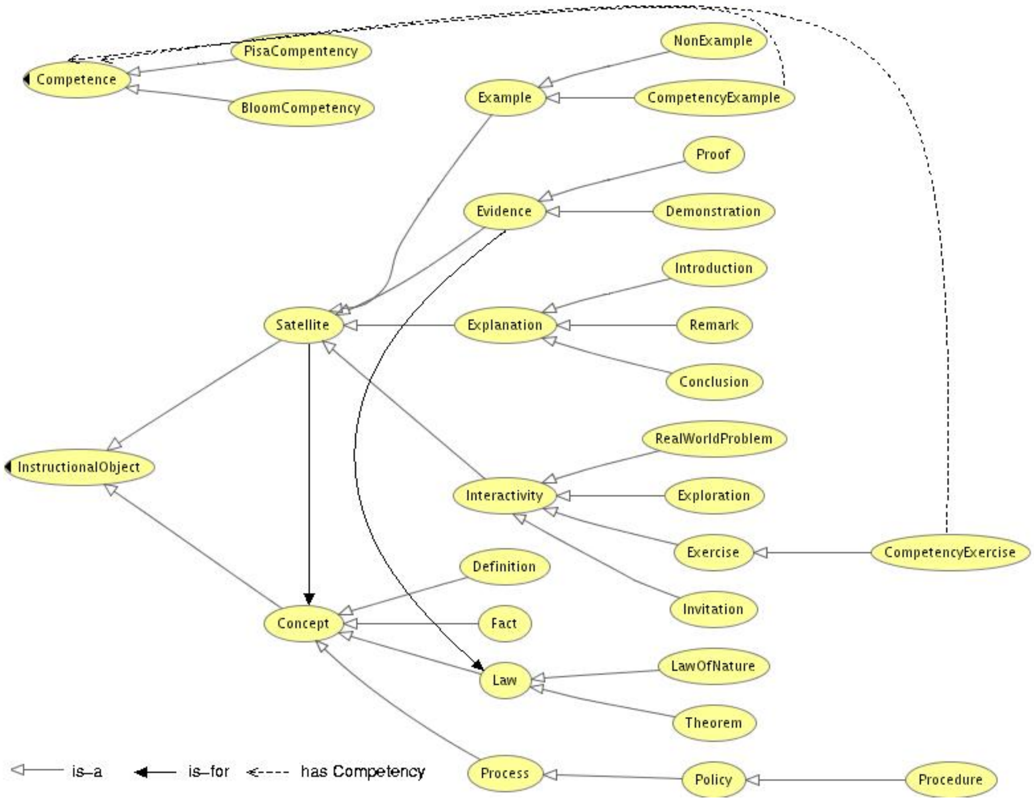

Figure 1. Overview on the ontology of instructional objects.

Theorem. A "theorem" is an instructional object which describes an idea that has been demonstrated as true. In mathematics, it describes a statement which can be proven true on the basis of explicit assumptions. An example is "The intersection of submonoids is a submonoid".

Process. "Process" and its subclasses describe a sequence of events. The deeper in the class hierarchy, the more formal and specialized they become. A process provides information on a flow of events that describes how something works and can involve several actors. Typical examples are "the process of digestion", and "how is someone hired in a company".

Policy. A “policy” describes a fixed or predetermined policy or mode of action. One principal actor can employ it as an informal direction for tasks or a guideline. Example: Curve sketching in mathematics.

Procedure. A “procedure” consists of a specified sequence of steps or formal instructions to achieve an end. It can be as formal as an algorithm. Typical examples are Euclid’s algorithm, or instructions to operate a machine.

Satellite. “Satellite” elements (the name was adopted from [15]) subsume instructional objects which provide additional information about the concepts. In principle, concepts provide all the information necessary to describe a domain. However, from an instructional point of view, the satellite objects contain crucial information. They motivate the learner, and offer engaging and challenging learning opportunities. Every satellite object offers information about one or several concepts. The identifiers of these concepts are enumerated in a “for” property.

Interactivity. An “interactivity” offers some kind of interactive aspect. An interactivity is more general than an exercise as it does not necessarily have a defined goal that the learner has to achieve. It is designed to develop or train a skill or ability related to a concept. The difficulty of an interactivity is represented in the property of the same name. The subclasses of “interactivity” do not capture technical aspects. In general, the way how an interactivity is realized, for instance as a multiple choice question, is independent of its instructional function. A well-designed multiple choice question can target knowledge as well as application of a concept.

Exploration. “Exploration” is an instructional object in which the user can freely explore aspects of a concept without a specified goal, or with a goal but no predefined solution path. Cognitive tools ([13],) or simulations are typical examples.

Real World Problem. “Real world problems” are frequently used in instructional design, especially in constructivist theories, e.g., [10]. They describe a situation from the learner’s daily private or professional life that involves open questions or problems.

Invitation. An “invitation” is a request to the learner to perform a specific, possibly meta-cognitive activity. For instance, it can consist of a call for discussion with other students.

Exercise An exercise is an interactive element that requires the learner’s feedback. The feedback can be evaluated (either automatically or manually) and an success ratio can be assigned to it.

CompetencyExercise. The class “CompetencyExercise” allows specifying precisely the educational objective an exercise aims the student to achieve, e.g., whether a learner can recall or apply a concept. A widely-used classification schema was designed by Bloom [1]. Recently, new classifications have emerged, for instance PISA's *literacies* [22]. An author can specify the competency an exercise trains by using the "hasCompetency" relation.

Example. An "example" serves to illustrate a concept. Similar to interactivities, it has a "difficulty" slot.

CompetencyExample. This subclass of "example" is analogous to the class "CompetencyExercise". It illustrates concepts with different educational objectives.

Non-Example. A "non-example" is an instructional object that is not an example of a concept but is often mistakenly thought of as one. It includes "counter-examples".

Evidence. An "evidence" provides supporting claims, for instance observations or proofs, made for a law or one of its subclasses. Therefore, the "for"-property of an evidence has a range the class "law".

Proof. A "proof" is more strict evidence. It can consist of a test or a formal derivation of a concept.

Demonstration. A "demonstration" consists of a situation in which is shown that a specific law holds. Experiments in physics or chemistry are typical examples of demonstrations.

Explanation. An "explanation" provides additional information about a concept. It elaborates on some aspect, points out important properties.

Introduction. An "introduction" contains information that leads the way to the concepts.

Conclusion. A "conclusion" sums up the main points of a concept.

Remark. A "remark" provides additional, not obligatory information about an aspect of a concept. It can contain interesting side information, or details on how the concept is related to other concepts.

4. Conclusion

The learning-resource-type is dead. LOM's learning-resource-type misses crucial information about a LO required for efficient searching and automatic processing.

Long live the learning-resource-type. Using the elements represented in the ontology of instructional objects, the learning-resource-type can prove to serve an important role for e-learning. It provides metadata crucial for instructional re-use.

An ontology is never completely stable and always the result of integrating different viewpoints. To stimulate discussion and to enhance the scope of the ontology, the author has set up a forum at his homepage[3]. It is the hope of the author that interested parties help to augment the ontology so that it can serve as a small step to bring e-learning to its full potential.

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