An Ontology-based framework for Authoring Tools in the Domain of Sustainable Energy Education.

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Abstract

This paper presents an “ontology-based” framework for the production of learning designs, focusing in the domain of sustainable energy education. An ontology of the sustainable energy development domain based on the Driving forces- Pressures-State- Impacts- Responses (DPSIR) framework of the European Environment Agency (EEA), and an educational model designed in compliance with the Institute of Electrical and Electronics Engineers Learning Object Metadata standard (IEEE LOM) and the Instructional Management Systems Learning Design specification (IMS LD), constitute the proposed in this paper framework in order to disprove the vagueness of “sustainable development”, and to enhance reusability and shareability of learning material respectively. We envisage this framework both as a means to support the authoring of learning scenarios and as a provisioning of a field for conversation about which should be the appropriate form of an authoring tool in this area, initiating the construction of a prototype and a consequent process of iterated improvements with the participation of practitioners. In this sense, an integrating approach for the representation of the learning design domain is kept, focusing on the concept of “mediating artefacts”.

Keywords: sustainable energy education, education for sustainable development, learning design, mediating artefact, learning object, ontology, authoring tool.
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The efficiency of the development of learning scenarios highly depends on the ability to reuse existing materials and expertise (Pawlowski & Bick, 2006). Initially the issue of reuse in education was focused in content, in the form of basic independent units (Learning Objects or LOs) (Pasin, 2005), for faster, more economic, and richer coverage of areas of a teaching course, capitalizing experts’ work and ability around the world (Mohan & Brooks, 2003).

However the simple provision of codified knowledge as data does not safeguard its understanding and using (Pawlowski & Bick, 2006). Therefore there is a tension to move from content-oriented to activity oriented approach, which promotes a model of the teacher as a designer and is enhanced from the parallel development of tools in the WWW, stimulating the emersion of communities of practice for the exchange of learning scenarios and experiences (Brouns et al., 2005; Pernin & Lejeune, 2006).

As the production and consumption of LOs is distributed, many standards and specifications have been developed for their standardization and generally for data exchange and processes management. A widespread standard for searching, retrieving, evaluating and using LOs, is this of IEEE LOM (IEEE Learning Technology Standards Committee [LTSC], 2002), even though, according to Ullrich (2004) it mixes pedagogic and technical information, and does not provide an adequate representation of pedagogical concepts. There are many languages and models for modelling activities in learning processes and is IMS LD that has been accepted as a specification since 2003. Even though it provides a general framework
An Ontology-based framework… 4

for constructing learning designs, its use is hard to non experts. As a consequence, the need for limitation of design options in the sense of provision of specific frames, as patterns, templates, primitives, best practices and/or taxonomies for fast and easy reproduction of learning designs arises (Bailey, Zalfan, Davis, Fill & Conole, 2006; Griffiths & Blat, 2005; McAndrew & Goodyear, 2007).

In general, to achieve interoperability and shareability, along with being usable, authoring tools must be compliant with specifications, without however being oriented to these but to the pedagogical task, that they have to support (TenCompetence Project, 2006). At any rate:

It seems unlikely that one all-encompassing notation system for representing and documenting learning designs will evolve. Instead, a toolkit of a number of representations each used at different times during the educational design process for different purposes seems to be a more plausible option. (Agostinho, 2008, p. 13).

In the context of learning design, ontologies usage covers a spectrum of roles. Ontologies can support more flexible handling of LOs as to employ just some specific parts of a LO, to reuse the same learning design in different contexts with different LOs, to personalize content of the same LO, and to develop more extensive LO and learning design search and ranking services (Knight, Gašević & Richards, 2006). According Mohan, Greer & McCalla (2003) it is necessary to associate LO metadata with domain ontologies since both play an important role in locating relevant LOs for a course.

Especially in authoring support, an instructional-objects ontology assists authors by allowing for better search facilities, by describing a conceptual model of
An Ontology-based framework… 5

the content structure, by offering a set of concepts to talk about instructional strategies and by providing an operational model (Ullrich, 2004).

Based on these concepts the paper introduces an “ontology-based” framework for the production of Learning Designs (learning scenarios compliant with IMS LD) in the field of sustainable energy education. In the next sections the rationale, the basic structure, the methodology and the ontology development of this framework are presented, along with an exemplification of its potential usefulness and some concluding remarks.

**Motivation and Rationale**

The current status in the field of sustainable energy education could be outlined by the following facts:

- Sustainable energy education is expected to contribute to the solution of a series of challenges – problems related with the dominant developmental models, taking into consideration that the energy production and use should provide “adequate energy services for satisfying basic human needs” while “should not endanger the quality of life of current and future generations and should not exceed the carrying capacity of ecosystems”. (Rogner & Popescu, 2000, p. 31).

- While the European Union (EU) has announced a certain sustainable energy policy in order to face these specific challenges, and the research in the field of energy is seeking towards certain aims according to the axis of 7th European Research Framework Programme (2007-2013) (EU, 2006), educational aspects related to energy policies are not part of the European educational curricula. Projection of knowledge acquired by research in this field onto such curricula could facilitate the spread and application of
European Union sustainable energy policy and would help citizens to form a sustainable orientated attitude towards the specific problems, contributing also potentially to the feedback of research procedure.

Regarding the shape of the educational approach that this field should have, the following issues must be taken into consideration:

a) The need for a practical and explicit definition of sustainability in virtue of the vagueness and the polysemous of the term (Robinson, 2004).

b) The need for flexibility in the learning process in order to follow the evolvement of conditions, technologies, and requirements (European Commission Directorate General of Energy and Transport [EC DG TREN], 2006b).

c) The need for a multilateral approach related to issues of sustainable energy, such as technological, cultural, economic, social, political, regulating and related to infrastructures; obviously it requires the contribution of many disciplines.

d) The necessity for teachers’ training, which becomes more urgent in some European countries (e.g. Greece), as relevant reports demonstrate a teacher’s lack of basic education on sustainable energy development (Papadimitriou, 2004; Skanavis, Petreniti & Giannopoulou, 2004; Spiropoulou, Antonakaki, Kontaxaki & Bouras, 2007).

e) The availability of abundant educational material about sustainable energy education issues, in various languages and forms, requiring however a substantial effort for evaluation, collection, adaptation and distribution.

f) The vast and ever-growing literature for learning theories, ideas and approaches with multiple competing claims, which comprises a very difficult and confusing field for educational practitioners, unless they are engaged in full-time research (Dillon & Ahlberg 2006).
An Ontology-based framework…

g) The not recommended development of a common set of tools for use by all
the schools of Europe, due to the cultural, social and teaching diversity of the
countries (EC DG TREN, 2006a).

h) The improvement of teaching quality and learning experience, when the
teachers adjust and refine materials provided rather than using 100 % readymade
materials (EC DG TREN, 2006b).

As a result, a reasonable approach to the issue is expected to include the
development of an educational authoring tool to support teachers in adaptation of
existing educational material and/or in production of new one, according to the needs
and the knowledge level of their students.

Accordingly, the issues that should be tackled are reflected in the following
research questions:

1. How should the field of sustainable energy development be specified in an
explicit way?

2. How the available educational material should be codified, in order to
provide information about its content, but also adapted to the local educational
environment for it to be reusable?

3. How teachers should be supported to the selection and utilization of the
available educational material, its adaptation to the local conditions, which will
exploit the existing theoretical and empiric pedagogic knowledge and will be, at the
same time, attractive?

4. What learning theory or model should be adopted?
The proposed framework

Based on literature review we introduce a framework that could be used as a base for the development of a prototype authoring tool and for the consequent process of iterated improvements with the participation of practitioners (Fig.1).

The basic framework components are a) the domain model and b) the educational model, which is comprised of a content model and a learning design model. Both models are based on ontologies. According Paquette (2007), in order to structure a knowledge domain in e-learning or knowledge management application a form of domain ontology is needed, since an alternative solution such as a tree organization, although it could reduce significantly the processing, is insufficient to describe the interrelations that tie the concept structures.

In our case the domain model specifies the basic concepts of sustainable energy development and the relations between them. In order to model the domain we rely on the DPSIR indicator-based framework (EEA, 2002).

The DPSIR framework depicts the sequence in which the events take place in the energy process, allows identifying the stages where there is a sustainability problem, and connects this problem with a potential response-solution. It can describe the state and the evolution of an energy model from a sustainable development perspective, starting from the demands that the energy sector receives from the society, represented as Driving forces (D). The Pressures (P) are the measures of the effects of energy production and consumption on the environment, the society and the economy, contributing to the change of their conditions (State) and producing an
impact on them (Impact). These four steps of analysis of sustainability of the energy sector are followed by the social actions (Responses) that feed back (D), (P), (S), and (I), modifying the interrelations of the energy process in order to limit, reduce or mitigate the Impacts (I) and attain a more sustainable energy system (De L. Hierro Ausin & Pérez-Arriaga, 2005).

As is mentioned in a document of EEA (1999), of particular importance are the links between phases of DPSIR, since they identify dynamic relations between origins and consequences of sustainability problems. These relations show that, in fact, DPSIR does not represent a simple sequential or circular scheme, but a very complex web of interacting factors. Thus for example the link between (D) and (P) is a function of eco-efficiency indicators as energy intensity, and emission factors (pressure intensity), since the link between (I) and (S) is a function of the carrying capacity of the thresholds of the human and eco-systems or, as is mentioned in another document (EEA, 2003), is a dose/response relationship. In further whether the society responds (R) to impacts (I) depends on how these impacts are perceived and evaluated by the community (EEA, 1999).

As far as learning design model is concerned we try to keep an integrating approach for the representation of the learning design domain. This is reasonable, because according Griffiths (2005) most teachers should not be expected to engage with the specification itself but only in the levels of adapting existing Units of Learning, or mixing and matching parts of them in order to construct a new one. Also, as mentioned by Conole, (2007), practitioners use a range of tools to support and guide their design of learning activities, while according (Falconer, et al., 2007) multiple representations are necessary as they give the ability to someone to view the designs from different perspectives.
Central point to this approach is the concept of “mediating artefacts” (Conole, 2008), that practitioners use in the authoring process, in order to, according activity theory, the gap between historical state of learning design and practitioners developmental stage be bridged.

The learning design model is considered in terms of the provision of supports to practitioners in order to construct a learning scenario and of ways to represent it. Also going a level up the model provides alternative solutions for the structure of the learning design tool itself, giving the flexibility to select the more appropriate features for a specific context. This should be particularly useful in a subsequent process of iterated improvements with the participation of practitioners.

In fact, such a model could act as repository of existing artefacts covering different level of abstraction, such as pedagogical models, patterns and generic learning designs, case studies, but also learning design processes, learning design conceptual models and representation formats used by other learning design tools. Furthermore the provision of a way to represent a learning event implies the existence of an underlying conceptual model, which specifies the basic elements of a learning process and their interrelationships, and of a representation module, which defines the representation format, the represented elements and probably a notation system.

As far as the content model is concerned, it is based on the IEEE LOM standard (IEEE LTSC, 2002), whilst mappings between concepts of these three models interconnect them. Thus for example the content model is associated with the “learning content”, a subclass of the learning design model. Also the content model is connected with the domain model via a mapping of LOs with the domain concepts, while learning objectives are associated to any domain concept connecting learning design model with the domain model.
An Ontology-based framework… 11

As a conclusion we could note that the specification of causal loops based on the DPSIR framework and related with sustainability problems is very important for the consistency of the approach. These loops connect the domain with the educational model since they can act as a backbone of a learning course.

Methodology of ontologies’ construction

In the top layer of the ontologies building procedure (Mizoguchi, 2004), we follow the stages of: Specification, Conceptualization, Formalization and Implementation; the activities of Evaluation, Documentation, Knowledge Acquisition and Maintenance are also interlaced in the ontologies development life cycle. We apply the evolving prototyping model because it is considered to be the most appropriate (Pinto & Martins, 2004), but also because of the fluidity and vagueness of the field of Sustainable Development. For the ontologies development we use the tool Protégé 3.4 beta.

In order to build the domain ontology from scratch we follow the process described by Noy & McGuinness (2001), as a set of middle and bottom layer guidelines (Mizoguchi, 2004), while keeping in mind that the ontology cannot contain all the information related to the domain and that it would be practical to structure at first an incomplete small ontology, which afterwards would be developed through continuous iterations (Mitrovic & Devedzic, 2002), in a collaborative fashion between practitioners and knowledge engineers (Kotis & Vouros, 2006). The basic concepts of the domain and their relations are found in the relative bibliography. The technical evaluation is carried out in the phases of Conceptualization and Formalization and it comprises of verification, supported via Protégé, and of validation/evaluation, which is carried out with the help of domain experts in a collaborative and argumentative manner (Kotis & Vouros, 2006). In a later phase, an assessment by the user is to be
An Ontology-based framework… 12

performed, with appropriate criteria such as understandability, usability, usefulness, abstraction, granularity, technical quality and portability (Gomez-Perez, 2001).

**Ontologies development**

Here we outline the ontologies’ structure and the rationale underlying their development. We should note that quotation marks are used when we refer to the classes of the ontology, and courier new fonts in the case of slots (properties of classes).

**Learning design model**

We envisage the learning design ontology both as a means to support the authoring of learning scenarios and in terms of provision of a field for conversation about which should be the appropriate form of an authoring tool in this area. In this sense we attempt to define the basic features that constitute a “Learning design tool”. We consider that a tool relies on a “Learning design conceptual model”, and potentially can provide a “Learning design process”, additional scaffolds in the form of “Guidelines”, “FAQs” or “Tips & hints”, and other stored artefacts, as “Learning models”, or “Learning design solutions”, abstract or contextualized. In general, in order to make a structure for storing existent practice in the learning design domain, we rely on the work of Conole (2008), classifying the tools and resources, which are used by practitioners to support the learning design process, as “Mediating artefacts” and the resulting by their aggregation artefacts as “Meta mediating artefacts” (Fig. 2).
An Ontology-based framework… 13

The “Learning design conceptual model” specifies the “Learning design elements” and their interrelationships, being also connected with a “Representation module”, which defines the way a “Learning design” is represented.

The “Learning design element” is the key concept for the provision of a formal structure for the description or the construction of a learning design. Its subclasses (“Learning objectives”, “Learning context”, “Activity”, “Role”, “Environment”, “Assessment”, “Act”) and their interrelationships are following the vocabulary and the basic directions of IMS LD specification (IMS GLC, 2003). The instantiation of any “Learning design element” is supported by stored “Controlled vocabularies” that are associated with them as potential or default value spaces, providing the ability to choose between a range of solutions.

For example, the revised Bloom’s taxonomy (Anderson & Krathwohl, 2001) is defined as default value space for the definition of “Learning objective” regarding the cognitive domain, while a number of similar artefacts constitute the potential value space (Fig. 3,4).

As far as the other subclasses of the “Learning design element” is concerned, we use in the most of cases the Dialog Plus taxonomy (DialogPlus Project, 2008) as default value space, in order to facilitate the completion of a learning design, since according to Griffiths & Blat (2005), this taxonomy compresses the definition of the
narrative, the representation and coding stages of IMS LD specification. Especially for the “Activity type” we use as alternative solution the Eight Learning Event Model (Leclerc & Poumay, 2005).

We actually use two levels of artefacts’ description. The first concerns the artefact itself, whilst the other presents information useful for its localization, selection and use for a specific case.

For example the “Learning design” and the “Learning design solution” refer to the same concept, but the first is defined as instance of the local formalization specified by the “Learning design element” class, while the “Learning design solution” is described by a pattern style form, which is used in order to unify the description of all the range of different approaches are used in the learning design realm (Fig. 5). This form includes title, context/audience, granularity, purpose/challenge, solution, example/generic, focus/approach, creator, references and related generic solutions, allowing between others the connection among an abstract learning design and its instantiations via the example/generic slot.

**Learning content model**

With regard to “Content model” (Fig. 6), the IEEE LOM standard (IEEE LTSC, 2002) is followed, so as to take advantage primarily of a complete syntax and semantic created by experts of the Learning Technology and secondarily to ensure the interoperability with similar systems (Capuano, De Santo, Marsella, Molinara & Salerno, 2000).
An Ontology-based framework… 15

The selected subset of the IEEE LOM elements for the description of “Content model” is depicted in Table 1. Elements’ selection was based on their simplicity and their utility for resource localization and sharing.

Modifications that have been made are the addition of the connections between domain concepts and curriculum disciplines, which are not explicitly mentioned by the standard, as well as discrimination between technical and instructive information in the learning resource type, as suggested by Ullrich (2004). Furthermore we conducted a literature review concerning the learning resource type and we stored relative vocabularies as alternative solutions in order to both interoperability and adaptation to the local conditions are achieved.

**Domain ontology**

As indicators can translate sustainability in a practical sense providing a deeper understanding of the main issues and highlighting important relations (International Atomic Energy Agency [IAEA], United Nations Department of Economic and Social Affairs) [UNDESA], Eurostat & International Energy Agency [IEA], 2005), we actually utilize sets of energy indicators of sustainable development in order to describe the dimensions of the sustainable energy development concept.

We rely on the DPSIR framework, which has been used by the EEA (2002) to connect energy and environment, and extended by De L. Hierro Ausin & Pérez-Arriaga (2005) in order to embody impacts of energy production and consumption not only on the environment but also on the society and the economy. We extend and enrich this last approach with more indicators derived from other sets of energy...
An Ontology-based framework… 16

indicators for sustainability (IAEA, UNDESA, IEA, Eurostat, & EEA, 2005; IAEA & IEA, 2001; EEA, 2008), since our aim is not to provide a tool for policy making in a specific context but a broad knowledge base for learning design, including as much as more concepts relative to sustainable energy development.

Except the amount of final energy demand that is the main driver, other indicators can be included, conditioning this amount and its effects on the environment, the society and the economy, as are energy efficiency, energy intensities of economic sectors, energy prices, pollutants and Green House Gas (GHG) emission intensities of energy consumption, status of abatement technology and auxiliary statistics (Fig. 7).

As far as the classes of “Pressure of energy development”, “State change of energy development”, and “Impact of energy development” are concerned, they are depicted in (Fig. 8), (Fig.9) and (Fig. 10) respectively.

We should note here that even though we assign any indicator to a concrete element of DPSIR framework, in fact an indicator can represent more than one DPSIR typology, depending on the context of analysis. A solution could be to define these additional relations via slots in the ontology. For example “Temperature” is assigned
An Ontology-based framework… 17

as a (D) subclass, since affects the amount of energy demand, but also a slot

conditions environment informs that describes the state of environment.

Of particular importance is the class “Response for sustainable energy development” since represents the solution or a mitigation of a sustainability problem. Some responses are considered as negative (D) since other aim to raise the eco-efficiency via the development and penetration of clean technologies (EEA, 1999).

We adopt and adapt an approach applied in (IAEA, IEA, 2001) and we define the (R) subclass in terms of the (D), (P), (S), or (I) subclasses that targets and positively affects respectively (Fig. 11).

The other slots include: response type, with values based on Environmental Sustainability Index (World Economic Forum, 2001); response actor, with values based on an approach presented by (Zhang & Fujiwara, 2007), distinguishing three categories of actors (government, civil society, firm); response level (global, regional, national, city, household, personal); and source.

Another important class is this of “Energy technology” (Fig.12). In this class, the basic directions for energy research in Europe, as they are specified by the 7th Framework-Programme (EU, 2006), are applied, in order for the educational process to be connected with the research.
As far as the other classes of the domain are concerned, a whole view of domain ontology is given (Fig. 13).

As a conclusion we should note that the organization of subclasses of the DPSIR types is not exhaustive. More concepts must be embodied, especially in the level of cities and/or households in order to the concept of sustainable energy development is more concrete and familiar to the learners.

**Connecting the parts: How the proposed framework contributes**

In this section we connect the fragments of the framework we described so far, in terms of its usefulness and its potential contribution in a learning design case.

According a report of EEA (2003) the provision of information on driving forces, impacts and policy responses is a common strategy to strengthen public support for policy measures.

The DPSIR framework can reflect a causal chain that links energy related human activities with their impacts on the society the environment and the economy. Thus it provides a base for a systemic approach of sustainability and we could identify causal loops based on this framework, connecting the origins, the consequences and potential solutions of sustainable energy development problems and guiding the structure of a relative learning design. Even though the real world is far more complex than can be expressed in simple causal relations these causal loops could support a life
cycle consideration of the impacts of learners’ behaviours as consumers on the environment, the society and the economy and could inform learners for their potential participation in response actions in order to these impacts be mitigated and/or eliminated. Furthermore the DPSIR framework provides a base to construct a visual representation of the learning design process. Consequently it seems to be reasonable to use this as a semiformal template for the construction of learning designs in sustainable energy education, providing an overall view of the theme to be learned and a solid structure tying the concepts involved.

An authoring tool based in general in the features of the framework we described so far and encompassing particularly the above approach, should provide a generic learning design process in the form of template including:

1. Selection of a theme relative to a sustainability problem;
2. Extraction of a corresponding DPSIR conceptual model from the domain ontology, connecting the problem with its origins and potential solutions;
3. Identification of desired learning outcomes appropriate for the concrete context, and connected with the domain concepts, that are nested inside the DPSIR model elements;
4. Arrangement of activities that could facilitate the achievement of these learning objectives;
5. Connection of these activities with appropriate resources, and assessment strategies.

This process can be facilitated by the proposed framework via:
An Ontology-based framework… 20

- the embodiment of controlled vocabularies supporting the articulation of the learning design elements (e.g. objectives, activities, context, assessment strategies);
- the mapping of concepts of domain with LOs and learning objectives, supporting respectively the retrieving of appropriate LOs and the storing of learning objectives associated with any domain concept, as long as these identified for one time;
- the provision of a formal way to express a learning design
- the provision, by querying and retrieving, of stored mediating artefacts in order to limit and frame the design options according to the existent experience in the educational domain.

This last support concerns the further framing of the learning design process via the incorporation (after the second step) of a step in the form of “Select and adapt a teaching template”. This implies either the selection of just one template corresponding to a “mediating artefact” (e.g. learning model, abstract learning design solution –pattern or generic learning design) or a combination of them.

Learning models are considered as the coarser frames of a learning design. According McAndrew & Goodyear, (2007) learning models derived from theory, literature or examples are in the top of an hierarchy ranging from more abstract forms of learning design representations to more contextualized, including also in turn, patterns as abstractions of generic designs, instantiations based in the interpretation and matching of these generic designs with learning content and tools, and executable versions in a runtime environment.

We conducted a literature review in order to specify learning models that were proposed or used successfully in the domain of Education for Sustainable
An Ontology-based framework Development (ESD). We identified two artefacts as more favourable: a framework suggested by McKeown & Dendinger (McKeown, 2002) for teaching, studying and analyzing environmental problems and; a model which has been tested and used in the ESD including the use of improved Vee heuristic, an action research framework, and the construction of concept maps (Ahlberg, Aanisma & Dillon, 2005; Ahlberg & Ahoranta, 2002). The first includes a set of eleven questions which could be considered as focus questions for the improved Vee Heuristic, and two questions that could help learners integrate knowledge into daily living, and should embodied in the value claims space (8th step) of Ahoranta’s improved Vee Heuristic version (Ahlberg & Ahoranta, 2002) (Fig 14).

An example case should be the combination of these two models for the further framing of the learning design process.

The information provided by the ontology gives the ability to a teacher to provide hints to the learners for a step by step construction of a conceptual map concerning a sustainability problem.

For example, in the case of air pollution issue the answer to the first question, “What are the main historical and current causes of an issue” is connected with a number of drivers, which are urban and interurban mobility by mode, energy intensity, population, pollutants emission intensity, energy efficiency, abatement technology status and energy pricing, since the question “What are the major currently implemented or proposed solutions?” is guided by a number of potential responses (Fig. 15).
In general the ontology fits well with this educational approach functioning as knowledge base for the construction and evaluation of a concept map in this area. An indicative mapping of the Mckeown & Dendinger’s framework to DPSIR elements is demonstrated in Table 2.

Alternative solutions should include learning models as Problem Based Learning and Project Based Learning.

Going one level down in the hierarchy we mentioned above, we identify more fine grained learning design representations described by the class “abstract learning design solution”. This class describes artefacts of various granularity, representation form, and source. They can range from a whole course approach to a single learning activity. The query for the selection of a corresponding template could be based in slots as focus/approach, granularity, or purpose/challenge addressed. This way teachers can choose activities suitable with the specific challenges they face, based in a variety of educational models and sequenced within learning design frameworks of coarser granularity.

A table including the purposes/challenges that the stored via the ontology abstract learning design solutions address, should be a significant feature of an authoring tool generally and for the prototype we are going to use in the next face of our research. Such a table could be used for the browsing/searching of stored learning designs and could facilitate the choosing by practitioners of learning designs suitable for a concrete learning situation. An indicative table with a sample of purposes/challenges addressed by the stored “abstract learning design
An Ontology-based framework… 23

solutions” is given (Table 3) and a query via Protégé for the localization of stored “abstract learning design solutions” that they address one such purpose/challenge (i.e. “You want your students to develop conceptions”) is depicted (Fig. 16). The sample corresponds to a range of patterns’ and generic learning designs’ types.

In further the framework should provide information for a range of alternative ways to represent the learning practice. This could include for example representations as Australian Universities Teaching Committee Visual Sequence (Agostinho, Oliver, Harper, Hedberg & Wills, 2002) or a matrix format followed in the LD Lite tool (Littlejohn & Pegler, 2007), and/or a Learning Activity Management System(LAMS) flowchart (Dalziel, 2003).

Concluding remarks and future development

In this work we introduced an “ontology-based” framework for an authoring tool in the domain of sustainable energy education. The basic components of the framework are the domain model and the educational model, which is comprised of content model and learning design model.

The domain model is relied on DPSIR framework (EEA, 1999) which provides a base for a systemic approach of sustainability, and we propose its use as a backbone for the construction of learning courses in the domain of sustainable energy education. As future work, more concepts shall be embodied in the DPSIR classes,
especially concerning the level of cities and/or households in order to, the concept of sustainable energy development be more concrete and familiar to the learners.

The educational model is designed in compliance with the IEEE LOM standard (IEEE LTSC, 2002) and provides a way to represent a learning design in a formal way following the controlled vocabulary and the basic directions of IMS LD specification (IMS GLC, 2003). In general, the support provided by the learning design model concerns either features embodied in the conceptual model of the provided formal expression of a learning design, or provision of stored “mediating artefacts”, via querying and retrieving. In order to unify the description of all the range of different learning design approaches we used a pattern style form.

We conjecture that by providing a variety of supports for the learning design process, ranging from informal solutions, as patterns, up to more constraint structures as the formal representation inspired by IMS LD specification, we should allow practitioners to make their own choice of the level of formality that they would like to adopt in their designs.

Also going a level up the framework provides alternative solutions for the structure of the learning design tool itself, giving the flexibility to select the more appropriate features for a specific context. This should be particularly useful for the future work which includes the construction of a prototype tool based on the proposed framework and a subsequent process of iterated improvements with the participation of teachers, having the character of formative evaluation of the ontology-based approach we proposed for the construction of learning designs in the domain of sustainable energy education.
An Ontology-based framework… 25

As first step to this next phase of our research is planned the evaluation of the level of success in which the stored abstract learning design solutions could be used by practitioners in order to construct learning designs fit to their context.

Our research approach is consistent with a pathway for future research efforts in the learning design domain, proposed by Agostinho (2008), underlying the need to work globally as one community and focusing in three research questions:

- How practitioners design activities?
- How current learning design representations are being used?
- How existing learning design representations could be integrated?
References


An Ontology-based framework… 27


An Ontology-based framework… 29


An Ontology-based framework… 30


An Ontology-based framework


An Ontology-based framework… 32


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An Ontology-based framework… 33


Table 1

*The slots of “Content model” according IEEE LOM categories*

<table>
<thead>
<tr>
<th>Category</th>
<th>Element name/slot</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. General</td>
<td>1.2. Title</td>
</tr>
<tr>
<td></td>
<td>1.3. Language</td>
</tr>
<tr>
<td></td>
<td>1.8. Aggregation Level</td>
</tr>
<tr>
<td>2. Life Cycle</td>
<td>2.3.3. Date</td>
</tr>
<tr>
<td>4. Technical</td>
<td>4.1 Format</td>
</tr>
<tr>
<td></td>
<td>4.2 Size</td>
</tr>
<tr>
<td></td>
<td>4.3 Location</td>
</tr>
<tr>
<td>5. Educational</td>
<td>5.2 Learning Resource Type</td>
</tr>
<tr>
<td></td>
<td>5.2 Technical Resource Type</td>
</tr>
<tr>
<td></td>
<td>5.3 Interactivity Level</td>
</tr>
<tr>
<td></td>
<td>5.5 Intended End User</td>
</tr>
<tr>
<td></td>
<td>5.6 Context</td>
</tr>
<tr>
<td></td>
<td>5.7 Typical Age Range</td>
</tr>
<tr>
<td></td>
<td>5.9 Typical Learning Time</td>
</tr>
<tr>
<td>6. Rights</td>
<td>6.1 Cost ,</td>
</tr>
<tr>
<td></td>
<td>6.3 Description</td>
</tr>
<tr>
<td>9. Classification</td>
<td>9.1 Relative concepts</td>
</tr>
<tr>
<td></td>
<td>9.1 Discipline</td>
</tr>
</tbody>
</table>
### Table 2

*Mapping between McKeown & Dendinger’s and DPSIR frameworks*

<table>
<thead>
<tr>
<th>Questions of McKeown &amp; Dendinger’s framework</th>
<th>Corresponding element of DPSIR framework</th>
</tr>
</thead>
<tbody>
<tr>
<td>What are the main historical and current causes of the issue?</td>
<td>D</td>
</tr>
<tr>
<td>What is the geographic scale, the spatial distribution, and the longevity of the issue?</td>
<td>Link between D &amp; P, distribution patterns</td>
</tr>
<tr>
<td>What are the major risks and consequences to the natural environment?</td>
<td>I</td>
</tr>
<tr>
<td>What are the major risks and consequences to human systems?</td>
<td>I</td>
</tr>
<tr>
<td>What are the economic implications?</td>
<td>I</td>
</tr>
<tr>
<td>What are the major currently implemented or proposed solutions?</td>
<td>R</td>
</tr>
<tr>
<td>What are the obstacles to these solutions?</td>
<td>Link between R &amp; D</td>
</tr>
<tr>
<td>What major social values are involved in or infringed upon by these solutions?</td>
<td>Link between R&amp;S</td>
</tr>
<tr>
<td>What group(s) of people would be adversely impacted by or bear the costs of these solutions?</td>
<td>Link between R&amp;I</td>
</tr>
<tr>
<td>What is the status of the problem and solutions?</td>
<td>Link between R&amp;I</td>
</tr>
<tr>
<td>How does this issue relate to other environmental issues?</td>
<td>I</td>
</tr>
<tr>
<td>You want your students to develop conceptions.</td>
<td></td>
</tr>
<tr>
<td>------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>You want to organise activities where each have something to contribute.</td>
<td></td>
</tr>
<tr>
<td>You want the students to conduct independent research.</td>
<td></td>
</tr>
<tr>
<td>You want to provide to learners a simulated environment for experiential learning.</td>
<td></td>
</tr>
<tr>
<td>You want your students to think about the past and argue about the future.</td>
<td></td>
</tr>
<tr>
<td>You want to focus on the whole picture.</td>
<td></td>
</tr>
<tr>
<td>You want your students to grasp the vastness of a new topic.</td>
<td></td>
</tr>
<tr>
<td>You want to maximize learning by engaging.</td>
<td></td>
</tr>
<tr>
<td>You want to take different skill levels and interests into account.</td>
<td></td>
</tr>
<tr>
<td>You want your students to acquire domain-specific or practical skills.</td>
<td></td>
</tr>
<tr>
<td>You want your students’ exposure to the idea that a problem can have many solutions.</td>
<td></td>
</tr>
<tr>
<td>You want to bridge the gap between the educational and real world.</td>
<td></td>
</tr>
<tr>
<td>You want to facilitate a sense of community for on-line students.</td>
<td></td>
</tr>
<tr>
<td>You want learners to organize prior knowledge and internalize new information.</td>
<td></td>
</tr>
<tr>
<td>You want your students to write a group paper or report.</td>
<td></td>
</tr>
<tr>
<td>You want your students to develop tools that they can use later on.</td>
<td></td>
</tr>
<tr>
<td>Participants forget the contents.</td>
<td></td>
</tr>
<tr>
<td>Participants are overwhelmed by theory.</td>
<td></td>
</tr>
<tr>
<td>Participants don't know how to learn outside the official learning environment.</td>
<td></td>
</tr>
<tr>
<td>Only a few students participate, the rest are quiet.</td>
<td></td>
</tr>
<tr>
<td>Participants don’t trust in their own knowledge.</td>
<td></td>
</tr>
<tr>
<td>Students have problems and questions and need quick responses.</td>
<td></td>
</tr>
</tbody>
</table>
Figure Captions

Figure 1. Functions supported by the framework

Figure 2. The classes of the Educational Model

Figure 3. The slot learning objective potential value space

Figure 4. An instance of the class “Learning objective”

Figure 5. An instance of the class “Abstract learning design solution”

Figure 6. An instance of the class “Content model”

Figure 7. The class “Driving force of energy development”

Figure 8. The class “Pressure of energy development”

Figure 9. The class “State change of energy development”

Figure 10. The class “Impact of energy development”

Figure 11. An instance of the class “Responses for sustainable energy development”.

Figure 12. The class “Energy technology”

Figure 13. The classes of sustainable energy development ontology

Figure 14. Modification of Ahlberg & Ahoranta’s (2002) improved Vee Heuristic, by integrating questions of McKeown & Dendinger’s framework.

Figure 15. A query via Protégé for the identification of response actions that affect positively “Air pollutants emission from energy systems”.

Figure 16. A query via Protégé for the localization of stored “Abstract learning design solutions” which address one purpose/ challenge.
Mediating Artefacts Repository inputs outputs functions supported by the models
Mediating artefact
- Learning design solution
- Learning model
- Controlled vocabulary
Metamediating artefact
- Aggregate metamediating artefact
- Scaffold metamediating artefact
- Mixed metamediating artefact
- Learning design conceptual model
- Learning design process
- Learning design
- Learning design element
- Activity
- Learning Environment
  - Role
  - Learning objective
  - Assessment
  - Learning context
  - Act
- Activity type
- Representation format
- Content model
<table>
<thead>
<tr>
<th>Name</th>
<th>Learning Objectives Instantiation</th>
</tr>
</thead>
<tbody>
<tr>
<td>objectives/ population</td>
<td>retrieving information about population's growth the last 20 years</td>
</tr>
<tr>
<td></td>
<td>Interpreting all data collected</td>
</tr>
<tr>
<td></td>
<td>executing a calculation related with population in the future</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Learning Objective Potential Value Space</th>
<th>As Served By</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Revised Bloom's taxonomy</strong></td>
<td>Population activity</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Learning Objective Type Value</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Remembering/Retrieving</td>
<td></td>
</tr>
<tr>
<td>Understanding/Interpreting</td>
<td></td>
</tr>
<tr>
<td>Applying/Executing</td>
<td></td>
</tr>
<tr>
<td>Focus/Approach</td>
<td>Discipline</td>
</tr>
<tr>
<td>---------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>Social constructivist</td>
<td>Physics</td>
</tr>
<tr>
<td></td>
<td>Engineering</td>
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<table>
<thead>
<tr>
<th>Title</th>
<th>Example/generic</th>
<th>Related Generic Solutions</th>
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</thead>
<tbody>
<tr>
<td>A Social constructivist learning design</td>
<td><a href="http://www.eframework.org/models/register_35290_18312">http://www.eframework.org/models/register_35290_18312</a></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Context/Audience</th>
<th>Granularity</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher Education</td>
<td>lesson/schedule</td>
<td>I. Falconer, M. Bretham, R. Oliver, L. Lockeley</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Creator</th>
<th>Purpose/challenge</th>
</tr>
</thead>
</table>
| LADB use cases 7, 16, Moodle learning design | You want learners work collaboratively to co-
<table>
<thead>
<tr>
<th>Date</th>
<th>2005</th>
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<tbody>
<tr>
<td>Name</td>
<td>Electricity from the Sun</td>
</tr>
<tr>
<td>Discipline</td>
<td>Physics, Mathematics, Language, Arts, Foreign Languages</td>
</tr>
<tr>
<td>Rights/Description</td>
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<td>Size</td>
<td>440000</td>
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<tr>
<td>Title</td>
<td>Electricity from the Sun</td>
</tr>
<tr>
<td>Typical Learning Time</td>
<td>P79h25M</td>
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<tr>
<td>Aggregation Level</td>
<td>3</td>
</tr>
<tr>
<td>Rights/cost</td>
<td>Free</td>
</tr>
<tr>
<td>Context</td>
<td>Primary education</td>
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<tr>
<td>Intended End User</td>
<td>Learner, Teacher</td>
</tr>
<tr>
<td>Technical Resource Type</td>
<td>Figure, Diagram</td>
</tr>
<tr>
<td>Location</td>
<td><a href="http://www.unilepspower.org/ldf/465_90-0101">http://www.unilepspower.org/ldf/465_90-0101</a></td>
</tr>
<tr>
<td>Learning Resource Type</td>
<td>Questionnaire, Problem Statement</td>
</tr>
<tr>
<td>Relative Concepts</td>
<td>Electric Energy Production from RES, Tech</td>
</tr>
</tbody>
</table>


Driving force of energy development

- Energy consumption
- Energy intensity
- Energy supply efficiency
- Intensity of use of forest resources as fuelwood

Auxiliary statistics
- Income inequality
- Local temperature and rainfall
- Gross Domestic Product
- Floor area per capita
- Population

- Urban and interurban mobility
- GHG intensity of energy consumption
- Emissions intensity of air pollutants
- Status of abatement technology
- Energy pricing
Pressure of energy development

- GHG emission from energy production and use
- Contaminant discharges in liquid effluents
- Air pollutants emission from energy systems
- Generation of radioactive wastes
- Accident as a result of energy use
- Generation of waste
- Land area taken up by energy facilities
- Radionuclides in atmospheric radioactive discharges
- Oil discharges into coastal waters
- Forests' income to energy prices
- Energy resources depletion
State change of energy development

- Land area where acidification exceeds critical load

Energy mix

- Net energy import dependence
- Indigenous energy production
- Quantity of accumulated radioactive wastes awaiting disposal
- Lifetime of proven recoverable reserves
- Lifetime of estimated energy resources
- Stock of critical fuels per corresponding fuel consumption
- Quantity of accumulated wastes awaiting disposal
- Rate of deforestation
- Share of household income spent on fuel and electricity
- Household energy use per income & fuel mix
- Ambient concentration of air pollutants in urban areas
- Expenditure on energy sector
- Ambient concentration of GHG
- Accident fatalities per energy produced by fuel chain
- Impact of energy development
  - Impact of air pollution
  - Climate change impact
    - Impact of the radioactive waste
  - External cost
    - Share of households without electricity or commercial energy
<table>
<thead>
<tr>
<th>Name</th>
<th>Response Type</th>
<th>Affects Positively</th>
</tr>
</thead>
<tbody>
<tr>
<td>Include externalities in full cost of energy</td>
<td>regulation &amp; management</td>
<td>Industry energy intensity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Passengers transport activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Freight transport activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Final energy intensity</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Response Actor</th>
<th>Source</th>
<th>Targets</th>
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<table>
<thead>
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<tbody>
<tr>
<td>global</td>
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<td></td>
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<tr>
<td>national</td>
<td></td>
<td></td>
</tr>
<tr>
<td>regional</td>
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</table>
Energy technology
- End-use energy technology
- Energy distribution technology
- Energy conversion technology
  - Electricity technology
  - Heating technology
- Clean Coal Tech
- CO2 Capture & storage tech
- Energy Efficiency & Save tech
**PLANNING**

2. Why do you study this issue? Why do you use time to solve this problem?

3. What do you know about the issue beforehand? Construct a concept map.

4. How are you planning to get an answer to the focus question?

**EVALUATION**

1. What are the main historical and current causes of air pollution?

7. What new knowledge did you construct? Construct a second concept map.

6. What kind of data did you gather?

8. What change can you make in your daily life and as next step, to lessen the problem.

**IMPLEMENTATION**

5. What did you do to answer the focus question?
- Decrease energy intensity through end-use energy efficiency
- Develop National Sustainable Development Strategy (Response)
- Eliminate energy subsidies except for the poor population (Response)
- Extend use of pollution abatement technologies (Response)
- Improve performance of pollution abatement technologies (Response)
- Include externalities in full cost of energy (Response for sustainability)
- Increase efficiency of energy supply, in particular for electricity
- Increase expenditure on air pollution abatement (Response)
- Increase fraction of CHP plants (Response for sustainability)
- Increase R&D expenditure for energy technology (Response)
- Increase share of natural gas in fuel mix (Response for sustainability)
- Increase share of public transport in passenger travel (Response)
- Increase share of renewables in fuel mix (Response for sustainability)
- Introduce taxes on polluting fuels (Response for sustainability)
- Implement and implement global agreements (Response for sustainability)
- Strengthen environmental regulations (Response for sustainability)
Query:
- Case-based learning design (Abstract learning design solution)
- Devised conceptions (critical - discussion or research-based)
- Devised conceptions (experimental - problem or case based)
- Devised conceptions (experimental - lab or field based) (Abets)
- Observe, Represent, Retain (Abstract learning design solution)