# Editorial: concepts and ontologies in web-based educational systems

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Web-based educational systems (WBES) present one of the fastest growing and challenging areas in educational technology research. To meet the high expectations and requirements of the educational community, current WBES research focuses on providing adaptation and various sorts of personalisation to the learner. Concept-based and ontology-oriented architectures come as a promising solution in the development of adaptive educational systems. This special edition of the *International Journal of Continuing Engineering Education and Lifelong Learning* is based on the best papers presented at the Workshop on 'Concepts and ontologies in web-based educational systems', held in Auckland, New Zealand, in conjunction with the 2002 International Conference on Computers in Education (ICCE'2002). The goal of the workshop was to explore issues related to the design and development of concept-based WBES and outline the state of the art in the research on ontology-aware systems that facilitate the reuse, sharing, and exchange of knowledge and components in the educational field.

Conceptual structures, such as concept maps, conceptual graphs, and topic maps, have an immense potential for organising, processing, and visualising subject domain knowledge and for building learner models in WBES. In concept-based courseware, they are used as an armature for linking learning objects to relevant concepts. This allows for concept-based course sequencing that supports adaptive courseware generation, concept-based information retrieval, conceptual visualisation, and navigation that help students get oriented within a subject domain and build up their own understanding and conceptual association, etc.

An even more challenging goal for WBES designers is the development of advanced WBES that offer adaptivity and intelligent support not only to learners but also to courseware authors and developers. This goal implies facilitating the courseware designers with means for reuse and sharing courseware content and functional components. Ontologies – well-founded and broadly agreed upon systems of concepts and relationships between them – can be used as common vocabularies for domain knowledge representation in specific domains that allow sharing, reuse, and exchange of knowledge bases and courseware functional components among different courses and instructors (authors). A further step in this direction would be to provide common understanding of the entire process of authoring of concept-based courseware (in terms of authoring tasks) that can be communicated to the support tools of adaptive courseware authoring systems. An authoring task ontology can efficiently support common reasoning over the processes accruing in concept-based courseware authoring, which can be applied in the reasoning strategies of the authoring support tools.

The papers included in this special edition of IJCEELL address most of the above-mentioned issues. They can be divided into three groups, reflecting three general approaches to employing conceptual structures and ontologies in educational systems, namely for

- supporting reusability, shareability, and interoperability of learning material
- abstract representation of learners and ontological reasoning about their knowledge
- supporting the process of WBES authoring.

Papers that seek to investigate ways of using conceptual structures and ontologies to support ontological reasoning about a learner's knowledge are by Apted and Kay, and Cimolino and Kay. Apted and Kay present a system, MECUREO, which automatically constructs an ontology from an existing digital dictionary by using a specification of keyword-relationship mapping. They describe it in the context of constructing an extensive lightweight ontology of computer science from the free online dictionary of computing (FOLDOC). The ontology is presented as a graph with nodes representing its concepts and weighted, directed edges representing its relationships. The system includes tools for querying the ontology (single- and multiple-concept queries) and visualising the results. The system *grows* the query concepts into a limited ontological graph that is intended to represent a collection of closely related concepts and the relationships between them. The results of the queries can be used for ontological reasoning, e.g. reasoning about concepts that a learner may know or is interested in if he or she knows or is interested in a certain concept(s).

Ontological knowledge representation facilitates building scrutable learner models. However, a critical problem in using concept maps for student modelling is related to verifying the maps before using them for reasoning about students' knowledge. The paper by Cimolino and Kay proposes an approach to verifying concept maps for eliciting a learner's understanding of a domain. They have developed a tool that allows a student to construct a concept map, which is then checked against the teacher's map and the student is prompted to reflect on and confirm or revise elements of his or her map.

The group of papers that are focused on using ontologies in the design and implementation of WBES to facilitate the reuse and sharing of educational components, knowledge, and conceptual structures, include the ones by Mitrovic and Devedzic, Seta and Umano, and Sicilia, García, Díaz, and Aedo. In their paper 'A model of multitutor ontology-based learning environments', Mitrovic and Devedzic propose a model that allows sharing of domain expertise (ontologies) and can be used as a framework for integrating multiple tutoring systems on the web. The tutors share common ontologies; thus each system is aware of the knowledge models used by the other systems in the environment. The proposed model focuses on the use of semantic markup and intelligent web services as techniques for representing, sharing, discovering, and reusing educational contents stored on educational servers. The authors apply their model to integrate several previously developed database tutors into a suite that enables interoperability of the tutors.

The paper by Seta and Umano proposes an ontology-based framework for the planning of problem solving workflow in learning processes, where the domain-independent problem solving tasks are modelled separately from the domain-dependent components (knowledge and resources). This separation allows the reuse, sharing, and inheritance of problem-solving expertise in various domains. The authors have developed a process ontology for planning problem solving and learning processes. This ontology is used to provide the learners with an explicit awareness of the purposes of their work, i.e. the interaction between the planning processes (triggered by monitoring and assessment results) and the problem solving and

learning processes. The authors have used the proposed framework to develop a system, KASSIST, which supports learners' modelling processes of problem-solving workflow and facilitates the reuse, sharing, and inheritance of problem-solving expertise.

Sicilia et al.'s work also focuses on the reusability of learning resources. They propose the concept of 'learning link' as an independent and reusable resource. Learning links can be annotated with the terms defined in link ontology and can express imprecision of relations for specific users or groups. The proposed model of learning links with support for vagueness and semantic typing enables the implementation of extended adaptive behaviours that may entail inferences and approximate reasoning. This approach complements existing approaches of using ontologies or conceptual structures to provide semantic interpretation to hypermedia nodes or contents. The authors describe an implementation of learning links, based on an SCORM-compliant runtime environment, that demonstrates their capabilities in the definition of learning-oriented adaptations.

The last two papers in this issue are related to using the ontological approach for construction of new generation authoring environments, theory-aware authoring environments. Hayashi, Ikeda, and Mizoguchi seek to provide an ontology-aware environment that supports the design of learning contents. They address this issue by converting the abstract concept of learning content design to an ontology and use this ontology to develop the design support environment *i*Designer. Their basic idea is to seek to make the usually implicit steps/results of designers' work explicit so that they can reflect better on the design process. This is realised by modelling a designer's intentions while designing and using the model to verify the validity of the designed learning contents. The support environment provides the designers with information for this verification by simulating the change of a learner's understanding in the learning contents model at a conceptual level, which is the intermediate result of the design. Further evaluation is needed to confirm the benefits of using the environment to learning contents designers.

In the same direction, Aroyo and Dicheva propose an ontological approach towards a common framework to formally describe the overall authoring process (in terms of primitive and composite tasks) in the context of concept-based web information systems (WIS) and their educational applications. They argue that by having ontological knowledge of the WIS application authoring process and being able to reason over it, an authoring support system will be able to perform various actions and provide hints and recommendations to the application author. A complete and clear separation of the content and the application related issues within WIS is proposed, which allows for better modelling of the application-related processes and for making accessible and retrievable external data in adaptive (user-oriented) WIS. The approach provides a link between high-level authors' tasks and low-level developers' functions and aims at supporting both WIS application authors and system developers. The authors illustrate their approach within AIMS, an educational information support system, and show the benefit of the ontology research for concept-based instructional systems.

The papers in this special issue provide a good view of the current tendencies in the emerging research on using conceptual structures and ontologies in educational systems. They share a common optimism about the role of ontologies in WBES and about the future of the ontology-aware web-based educational systems, which trace the path to the educational semantic web.

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