Ontological Engineering of Instruction: A Perspective

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In order to design an Intelligent Instructional System (IIS), the designer has to know what instructional theories and models may provide appropriate principles and strategies, what functional components are necessary for reaching instructional goals and objectives, what pedagogical actions are appropriate for each situation, what architecture and strategy are appropriate for supporting these actions, how to control the system behavior to achieve a coherent learning support process, and how to organize domain knowledge. However, these fundamental characteristics of an IIS are often implicit, vague or ill-formed. Despite much theoretical research and implementation of IISs, there is little to link the two, and relations between research and implementation are not strong. What is needed is a well-formed system of concepts which summarizes what we have learned to date and characterizes areas of agreement, as well as areas where disagreements indicate the need for further elaboration. A solution to this problem could be the ontological engineering of instruction.

An ontology consists of a task ontology which characterizes the computational architecture of a knowledge-based system which performs a task, and domain ontology which characterizes the domain knowledge where the task is performed, such as diagnosis, monitoring, scheduling, or design. Instruction is a task, as is supporting the learning process. Task ontology might provide an effective methodology and vocabulary for both analyzing and synthesizing knowledge-based systems to which IISs belong, with benefits such as: a common vocabulary, making knowledge explicit, systematization, standardization, and meta-model functionality. This functionality suggests the possibility of an ontology-aware authoring functionality which could be very intelligent in the sense that it would know what model would help authors. Mizoguchi [1] has proposed the following three levels of ontologies. Level 1 is a structured collection of terms. The most fundamental task in ontology development is articulation of the world of interest; that is, elicitation of concepts and identifying a is-a hierarchy among them. Level 2 adds formal definitions to prevent unexpected interpretation of the concepts and necessary relations and constraints also formally defined as a set of axioms. Definitions are declarative and formal to enable computers to interpret them. The interpretability of an ontology at this level enables computers to answer questions about the models built based on the ontology. In level 3, an ontology becomes executable in the sense that models built based on it run using modules provided by some of the abstract codes associated with concepts in the ontology. Thus, it can answer questions about runtime performance of the models.

Since an IIS needs terms/concepts concerning pedagogical actions to ground the functionality in concrete actions, the justification should be given by theories, and the source of intelligence of the systems should come from the knowledge bases containing this knowledge. Easy access to educational theories would be valuable to both to human and computer agents. For humans, conventional browsers are enough. For computers, somewhat deeper operationality is required. Ontological Engineering helps specify higher level functionality of IISs: it bridges the gap between human knowledge and knowledge in the knowledge bases. An Ontology of Instruction could pave the way for the building of an ID-aware Authoring Environment for IISs. An authoring agent could explain relevant theories in response to an authors request; it could give the author some possible justifications for teaching and learning strategies from a theoretical point of view. An Instructional knowledge server on the Web could have such a support functionality, and be called an Instructional Ontology-aware environment. In order to reach this goal, a first step is to extract an ontology from existing Instructional theories and from Instructional Design models.

The first challenge is to have computers mediate the sharing of our knowledge, with a common vocabulary for representing the knowledge, in order to do meaningful mediation using common terms. The level 1 ontology plays a sufficient role for this goal, which is to share primitive concepts in terms that can describe the knowledge and theories. Instructional knowledge could be described in terms of a shared vocabulary, based on an on-line glossary (http://garnet.acns.fsu.edu/~www6982/glossary.html), on descriptions of theories (http://www.cudenver.edu/~mryder/itc_data/theory.html), and on taxonomies of ID knowledge [2]. The second challenge is to extend this sharing from among humans to among computers. Level 2 introduces definitions of each term and relations richer than in level 1 by using axioms. An axiom relates a couple of concepts semantically, which makes computers partially understand the rationale of the configuration of the world of interest, here learning and instruction. The operationalization of this knowledge leads to the building of IISs. This requires a level 3 ontology to enable computers run the code corresponding to the activity-related concepts. Knowledge at this level is mainly concerned with task ontology which contains concepts of action of the system in performing a specific task (instruction, learning support). The knowledge server communicates with humans who need help in finding knowledge appropriate for their goals. Thus, such authoring environments can discuss with authors about the appropriateness of strategies adopted with the help of the knowledge server. Future IISs developed in this way would behave in a seamless flow of knowledge from designers onto learners.

Building an Ontology of Instruction requires us to identify the concepts that will constitute this ontology. Instructional Science (IS) consists of theories, models and methodologies for Instruction and for Research on Instruction; it builds upon Learning Sciences, Cognitive Sciences and Systems Science. Instructional Science is a Design Science, as defined by Simon, and it has both descriptive and prescriptive components; the prescriptive part forms what is called Instructional Design. Instructional Design (ID) is a systemic and systematic process of applying strategies and techniques derived from behavioral, cognitive, and constructivist theories to the solution of instructional problems; it represents the systematic application of theory and other organized knowledge to the task of instructional design and development (http://www.unc.edu/cit/guides/irg-22.html). ID is domain-independent, generic, theory-based; it contains concepts, rules and principles. The state of the art in ID shows concerns about unification and integration [3,4], as well about taxonomic issues [2], toward a better integration of taxonomic concepts between learning domains - affective, cognitive and psychomotor. Instructional Knowledge has been used in the field of ITS for approximately a quarter of a century, and experience gained in the building of ITSs shows that they are often curriculum or topic oriented; learner modeling is oriented toward control; existing instructional knowledge is sometimes used more to serve technical design needs rather than learning needs.

Recent efforts in the AIED community appeared toward ITS-Authoring [5,6,7,8]. Murray [9] indicates trends toward inclusion, if not integration, of four components : Tools for Content, Instructional Strategy, Student Model, and Interface Design. Intelligent Authoring Environments that can support the building of ITSs need foundations in Instructional Science, with a coherent set of concepts and principles for building quality products. Such environments should provide authors with a choice between long established knowledge and more recent developments, such as Reigeluth s proposal to consider learners as co-designers of their instruction, where learners have the capability to request the computer system to use some instructional strategies, as well as the computer deciding on some strategies based on learner input [10]. An ID-aware Authoring System would know the distinction between designing an IIS, an Interactive Learning Environment (ILE), and an Open Learning Environmnet (OLE). It would provide the requirements and decisions to be made in each case before starting any authoring, in order to have a complete, coherent and congruent product. Requirements in designing an IIS rely on the knowledge of student and context as much as of the didactic knowledge. Explicit statements would be to specify the conditions of learning for which the system has been thought, as: complement, supplement or replacement of teaching. Designing an ILE requires a different set of decisions, that can refer to either individual or team-based learning, with a philosophy such as situated learning; having fundamentals for a constructivist design for example, helps us in making explicit statements about the design principles used, the authoring decisions made, and about their pedagogical finality and effectiveness. Designing an OLE contains challenges that seem to be particularly in phase with the spirit of the time as we step into the XXIst century. Being open can mean keeping your eyes open, and also being open-minded. What does it mean for an OLE? Requirements for an OLE typically are: 1) to know about external learning events, both those planned and the ones that happened, 2) to be able to reason, make hypothesis and decisions based on both internal and external events, 3) to be flexible in adapting instructional strategies based on culture or affects.

Explorations in the direction of an Ontology of Instruction for ID-aware authoring environments have been described. Conclusions are that an Ontology of Instruction would be beneficial to the development of the field; it would also benefit the field of Instructional Science as it has the capacity to stimulate reformulations and the building of taxonomies, while, at the same time, consider new ideas and paradigms a richness. Reigeluth s claim for a new paradigm of Instructional Theory [10] contains keywords such as: customisation, autonomy, co-operation, shared decision-making, initiative, diversity, networking, holism, process-oriented, and Learner as King !

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