The Foundations of an Ontology-Aware Authoring System for Collaborative Learning

1. PROBLEM AND MOTIVATION

In recent years, with the increasing use of technology, Artificial Intelligence has been gradually and successfully introduced into Education. However, major challenges remain. Among these, we are concerned how to represent the "knowledge" of intelligent authoring systems (IAS) and then how to use this knowledge efficiently, especially within the context of collaborative learning.

Usual approaches provide their systems with a kind of "expertise" using a set of heuristics and domain theories built in the procedures (programming languages). This means that the programmers, not the systems, have an understanding of the knowledge being used. As a result, these systems cannot share or build new knowledge, ignore the existence of theories on which the knowledge is based, and finally cannot justify their recommendations systematically and scientifically [2;16] . As pointed out by [16]: "neither inference techniques nor beautiful theoretical formalism can contribute to an improvement of the situation".

To develop IAS to support collaborative learning (CL) is especially challenging in view of knowledge representation. Current knowledge concerning CL is based on various learning theories, which are always expressed in natural language and are particularly complex given the context of group learning where the synergy among learner's interactions affects the learning processes and hence learning outcome. It is in fact currently difficult for both humans and computers to clearly understand and differentiate between the various learning theories, yet, without their explicit representation, it is difficult to support the design of group activities based on well-grounded theoretical knowledge.

Our approach calls upon techniques of ontological engineering to, at first, establish a common understanding of what a learning theory is by representing it in terms of its explicitness, formalism, concepts and vocabulary. This makes theories understandable both by computers and humans. We then propose sophisticated techniques of reasoning on these theories which allows dynamic guiding of instructional planning and an effective design of learning processes.

2. BACKGROUND AND RELATED WORK

Ontological engineering or ontology research is a quite new field in Computer science. It started in the early 90's in the knowledge base community [17] and has been widely recognized due to its practical applicability and its potential to solve many problems related to different field, as for instance: information processing [15], semantic web [1], medicine[5], knowledge management [8], teaching and learning [9;19;23], among others. In practical terms ontological engineering helps to achieve the following [6;17]: (a) A common vocabulary and highly structured definition of concepts; (b) semantic interoperability and high expressiveness; (c) coherence and systematization of knowledge; and (d) meta-models and foundations for solving different problems in a variety of contexts.

In CSCL (Computer Supported Collaborative Learning) research previous works using ontologies have been successfully applied to solve problems such as: group formation [22], CL representing [10], interaction analysis [11] and modeling of learner's development [12]. Our approach uses these previous achievements to (a) propose a formalization of learning theory for CL; (b) to create new techniques for effective design and analysis of group learning activities; and finally, (c) to provide foundations for a complete ontology-aware authoring system which can "really understand" the theories and reasoning based on their semantics.

3. APROACH AND UNIQUENESS

Until now, with the achievements of using ontologies in CSCL presented in section 2, it is possible to successfully identify which kind of collaboration occurs in a CL session, understanding the essence of the group's interactions, and to estimate the expected educational benefits for each member. Nevertheless, there are some limitations: (a) there is no relation among interaction's models and learner's development; (b) we can not define what a learning theory is explaining for example, the learner's development through a set of events; (c) difficulty to blend learning theories rationally based on the models; and (d) There is no way to intervene while a CL session is taking place. For example, if a learner teaching another learner misunderstands the content, he will transfers the misunderstanding from the beginning until the end of the CL session.

To deal with the problems presented above, we analyze seven different learning theories [3;4;7;14;20;21;24], frequently used to supported CSCL activities, to clarify the relationships among interaction patterns, learning strategies, learner's roles and learning goals. Thus, based on previous models of interaction processes and learner's growth, presented respectively in [11] and [12], we defined an ontological structure to represent an excerpt of Learning Theory concept (part of this structure is illustrated in [13] at Figure 3).

Through this structure we proposed a model called GMIP: Growth Model Improved by Interaction Patterns that can be represented as a graph [12;13]. This graph has twenty states to represent the levels of the learner's development at a certain moment of learning and directed arrows to connect them. Each state is shortly represented by s(x,y). The x represents the stage of knowledge acquisition, while the y represents the stage of skill development. The directed arrows have labeled interactions that correspond to a set of activities extracted from theories [11;13] to facilitate the transitions between states (an example of this graph is illustrated in [13] at Figure 5).

For users (designers, teachers, educators), the GMIP allows the graphical visualization of learning theories, considering the relationships among strategies, interaction, roles and goals. Thus, users can quickly understand the theories, their benefits and how to propose sequence of activities in compliance with them. For computers, it provides a formal structure which allows systems to "understand" the theories and to reasoning about actions (and other features) prescribed by them. With such possibility we can compare real interactions with interactions prescribed by theories to find problems in learning processes or to estimate educational benefits for learners. Furthermore, it is possible to, given a learner's initial stage, suggest the best sequence of activities based on one or many theories that can lead the learner to achieve desired goals.

4. RESULTS AND CONTRIBUTIONS

The main contribution our research is to provide an ontological structure to describe learning theories and create techniques to use it rationally. Thus, it becomes the foundation to support the development of ontology-aware authoring systems by solving, at least partially, the problems presented in [16] including those discussed in the beginning of section 1 and 3. The proposed structure allows us to work with theories at the macro (strategies and goals) and micro levels (interactions and roles) and to create a link between them. This link clarifies, more precisely, how interactions can affect learner's development which helps designers to select interactions and roles for each learner with justifications based on the theories.

On the basis of our formal description of learning theories we also contribute by offering new alternatives for designing, guiding and analyzing CL sessions while a CL session is not finished, as opposed to adjustments after it has ended, as is usually the case. And finally, we create a rational method to blend learning theories that considers the levels macro and micro of each theory. Thus, we can combine semi-automatically different strategies at the macro-level and propose consistent sequence of activities for learner in a group at the micro-level which gives a feasible solution for the problem of designing inconsistent learning process discussed in [18]. That is, with our model we realize a guideline to blend learning theories which preserves the consistency of the learning process and guarantee a suitable path to achieve desired benefits.

The possibility of clarifying what a CL session is and to amplify its educational benefits has been a great challenge. In this context our approach offers a declarative representation of learning theories allowing computational support for analysis and designing of CL sessions in compliance with theoretical procedures and, because it can be explicitly demonstrated, is much more convincing and flexible than usual approaches.

5. REFERENCES

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