Computers & Education 54 (2010) 809–834

Contents lists available at ScienceDirect

Computers & Education

journal homepage: www.elsevier.com/locate/compedu

The foundations of a theory-aware authoring tool for CSCL design

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ARTICLE INFO

Article history:
Received 19 January 2009
Received in revised form 1 September 2009
Accepted 3 September 2009

Keywords:
Ontology
Intelligent authoring system
CSCL
Collaborative learning design

ABSTRACT

One of the most useful ways to enhance collaboration is to create scenarios where learners are able to interact more effectively. Nevertheless, the design of pedagogically sound and well-thought-out collaborative learning scenarios is a complex issue. This is due to the context of group learning where the synergy among learners' interactions affects learning processes and, hence, the learning outcome. Although many advances have been made to support the designing of collaborative learning scenarios through technology, a more systematic approach is lacking. With the limitations of the current designing methods and tools, it is difficult to develop intelligent authoring systems that can guide users in order to produce more effective collaboration. One of the main difficulties with creating a more consistent (computer-understandable) approach to designing collaboration is the necessity of proposing better ways to formalize the group learning processes. In this paper, we present an innovative approach that uses ontologies and concepts from learning theories to create a framework that represents collaborative learning and its processes. Ontologies provide the necessary formalization to represent collaboration, while learning theories provide the concepts to justify and support the development of effective learning scenarios. Such an approach contributes to establish the foundations for the development of the next generation of intelligent authoring systems referred to as theory-aware systems. To verify the viability and usefulness of our proposed ontological framework in the context of systematic design, the development and use of an intelligent authoring tool for CSCL design is presented. This system is able to reason on ontologies to give suggestions that help users to create theory-compliant collaborative learning scenarios. We carried out several experiments with teachers in a geometry drawing course and the results indicate that the system helps teachers to create and interchange their scenarios more easily and facilitates the selection of important pedagogical strategies that influence positively the designing and effectiveness of group activities.

1. Introduction

For many years researchers and practitioners have been doing research on computer-supported collaborative learning (CSCL) to improve the development of computational programs that can increase learning outcomes, and support collaboration in classrooms and e-learning environments (Dillenbourg, 1999; Stahl, Koschmann, & Suthers, 2006). Among the many topics related to CSCL, one of the most important is the design of group activities.

Through the design of CL activities, a teacher/designer can define, for example, the overall learning goals for each learner and for the entire group, establish the relationship between learning goals and the group structure, and form groups in an appropriate way enabling learners to obtain more benefit from interacting with their peers. Without a well-thought-out design for CL scenarios the chance of having an effective collaboration decreases considerably. This conclusion is based on the fact that many researchers have reported that the inadequate design of CL scenarios is one of the main causes of unsuccessful group learning (Dillenbourg, 2002; Fiechtner & Davis, 1985).

In spite of the importance of CL design, researchers in the field have noted problems with the lack of a more systematic approach (computer-understandable approach) that can be used by humans and computers to support pedagogically sound group formation and the satisfactory design of CL activities (Hernandez-Leo et al., 2006; Isotani, Inaba, Ikeda, & Mizoguchi, 2009; Strijbos, Martens, Jochems, & Broers, 2004). One of the reasons for this is the difficulty of creating models that formally represent the CL processes, the interactions between learners, and the impact of these interactions on the learners' development (Inaba, Ohkubo, Ikeda, & Mizoguchi, 2002; Strijbos, Martens, & Jochems, 2004).

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doi:10.1016/j.compedu.2009.09.010

According to Dillenbourg (2002) and Suthers, Dwyer, Medina, and Vatrapu (2007), the key to comprehending collaborative learning is to gain an understanding of the wealth of the interactions between individuals. The next step is to use this understanding to help with the design of CL scenarios. Hernandez-Leo et al. (2006) and Inaba, Ikeda, and Mizoguchi (2003) emphasize that what is needed is the development of better ways of formalizing the flow of collaborative learning processes. In order to provide an effective CL scenario is essential to establish appropriate parameters (goals and tasks) for each learner and to structure the group appropriately. To achieve this we need understandable models to represent CL activities which are based on the interactions between individuals.

Numerous learning theories have been developed and evaluated extensively to facilitate an in-depth understanding of collaborative learning and the impact of interactions in group activities. Some examples of this are: Legitimate Peripheral Participant – LPP (Lave & Wenger, 1991), Anchored Instruction (CTGV – Cognition & technology group at Vanderbilt, 1992), and Cognitive Apprenticeship (Collins, 1991). Although learning theories are not complete in terms of their ability to describe learning, and the different viewpoints sometimes contradict each other, they can provide and explain some essential conditions in which learners are able to learn more effectively. In order to explain the learning process, usually a learning theory gives information about what happens inside the learner's mind. This process, whether explicitly or implicitly, provides the context, learning activities, group structures, learning objects, target goals (knowledge/skills), and various other parameters that affect learning. These parameters described in learning theories are essential for structuring the group and designing pedagogically sound CL scenarios.

Nevertheless, the selection of an appropriate theory to design CL scenarios for specific situations is a difficult and time-consuming task. One of the reasons for this is the difficulty in understanding the theories due to their complexity and ambiguity. Each theory offers a different point of view, level of aggregation, perspective, and emphasis. Furthermore, they are written in natural language and, as a result, there is no common vocabulary to describe their characteristics. Thus, to systematically design effective CL scenarios based on learning theories it is necessary to extract the essential concepts of the theories and create models/frameworks to represent them formally and explicitly.

Through the use of ontologies and ontological engineering, many interesting results have been obtained which can help to organize the conceptual knowledge of learning theories (Ikeda, Go, & Mizoguchi, 1997; Inaba& Mizoguchi, 2004). An ontology is a system of fundamental concepts semantically represented in a computer-understandable manner (Mizoguchi, Hayashi, & Bourdeau, 2007). The use of ontologies allows for the creation of conceptual frameworks and models that describe theories, taking into consideration their similarities and differences. Furthermore, it also helps in the development of sharable and reusable knowledge that can be incorporated into a wide variety of intelligent systems and applications. In this work we present the collaborative learning ontology (CL ontology) that our group has developed to date. We demonstrate how it can be used to propose useful models to clarify the relationships between desired interaction patterns, the learner's knowledge acquisition process, and the skills development process in CL sessions. Through the clarification of concepts and the development of models based on ontologies, we intend to aid in the design of effective and pedagogically sound CL scenarios. Finally, we will explore some of the challenges to develop a prototype of an authoring system that exemplifies how the next generation of intelligent systems, referred to as **theory-aware systems**, can be created and used to help the design of collaborative tasks with educational purposes.

In the following sections we initially contextualize our work, showing some of the achievements and limitations of the current research on CSCL design. Then we introduce our previous work about the CL Ontology, placing emphasis on concepts that help to understand the interaction process and the learner's development. Next, an ontology-based model referred to as GMIP is presented which clarifies the relationship between interactions and the learner's growth, offering a formal way to explain the learning development process through a set of collaborative learning activities. Finally, we present the development and utilization of an authoring tool that support the designing of theory-based CL scenarios.

2. Related work on CSCL design

Free collaboration does not always produce satisfactory learning outcomes (Dillenbourg, 2002; Barkley et al., 2005). One of the main reasons highlighted by Fiechtner and Davis (1985) and Isotani et al. (2009), is that an unstructured collaboration often leads to CL sessions being filled with meaningless interactions. Such interactions can be defined as those that interfere with the good "health" of the group and the progress of collaboration among group members. Some examples of the large number of meaningless interactions are: arguments between members; long discussions without any concrete results; "off-topic" discussions; abrupt interruptions while effective collaboration is taking place; and excessive participation (of one member) or lack of it. In order to avoid these problems and enhance the probability that meaningful interactions occur during collaborative learning processes (such as conflict resolution, explanation, and mutual regulation); it is necessary to form groups properly and to propose CL activities that foster the occurrence of desired interactions among learners (Alfonseca et al., 2006; Tchounikine, 2008).

To facilitate the design of effective CL sessions, the CSCL community has put a great deal of effort into defining CSCL scripts (Weinberger et al., 2005). These scripts are guidelines that help to support structured collaboration by facilitating the description of collaborative tasks. Through the use of scripts, it is possible to describe collaboration and CL processes, including their different components (variables/conditions) and mechanisms (Miao, Hoeksema, Hoppe, & Harrer, 2005). According to Kobbe et al. (2007) the main **components** to describe scripts are:

(a) *Participants* – meaning the total number of participants (e.g. two students per group) and the participant characteristics (e.g. different knowledge or opinions).
(b) *Activities* – a list of activities forming a hierarchical structure in which any coarse-grained activity can be decomposed into more fine-grained activities and vice versa.
(c) *Roles* – allow/foster a participant to behave in a certain manner that helps him to achieve his/her goal while supporting other participants to achieve their goals as well (e.g. tutor and tutee roles).
(d) *Resources* – learning objects that can be used by participants to support the learning process.
(e) *Groups* – a set of participants which are grouped according to the participants' characteristics, activities, constraints, and the available learning objects. Usually groups form a hierarchical structure whereby the larger groups are composed of smaller ones.