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Computer Supported Collaborative Learning Scenarios: And External Representations for Promoting Them

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INTRODUCTION

There are many ways in which information technology (IT) can be integrated into the curriculum. IT can, for example, enable access to learning material and resources, it can feature learners' communication, and also provide instructional elements for the learners. The exact method by which IT is applied to the learning situation is however dependant upon the scenario in which it is required. This article is about computer-supported collaborative learning scenarios. These are characterised by the fact that two or more learners work together to acquire knowledge about a particular topic. Learners may sit together in front of the same computer screen and work in a learning environment, or they may be spatially or temporally separated and use IT for their communication as well as for access to the learning environment. This communication may use chatrooms, newsgroups, or one of the forms of audio-visual communication, such as videoconferencing. The method of communication should be adapted to best fit the learning scenario for which it is being applied (Ertl, Kopp, & Mandl, 2007). Whether or not the collaboration partners are in the same place, the computer screen and its contents are always the central element in the computer supported learning environment. The information displayed on the screen is used to focus the collaborative learning process on particular aspects of the learning task, for example, on ontologies and argumentation moves (Ertl, Fischer, & Mandl, 2006; Suthers & Hundhausen, 2003). Consequently, the design of the screen is of great importance, and an improvement in this area can be an improvement in the instructional make up of a learning environment. It must be noted that the term 'design' in this case is not used to mean the particular aspects of usability, but refers to development of an instructional prestructure of the shared screen (Ertl et al., 2006; Fischer, Bruhn, Gräsel, & Mandl, 2002; Suthers & Hundhausen, 2003). This structure can be seen as an external representation of the instructor's knowledge about the topic at hand, and is given to the learners as instructional support.

BACKGROUND

The term 'external representations' is very broad and can be described as knowledge and structure which are displayed by physical symbols, objects, or dimensions (Zhang, 1997). External representations comprise of text information, such as a book, visualisations, or structure and guidelines (e.g. in the style of templates) (Löhner & van Joolingen, 2001; Zhang, 1997). External representations offer different features for varying scenarios of collaborative learning. They provide a permanent *display* of knowledge and structures (Larkin, 1989; Pächter, 1996) and allow learners a permanent *access* to contents (Dennis & Valacich, 1999).

External representations may also guide the learning process if they provide an instructional prestructure to the learners; for example, verbal guidelines or visual structure for aspects that are of particular importance to their task. This representational structure focuses learners' attention on aspects that might otherwise be neglected. Suthers and Hundhausen (2003) call this 'representational guidance.' The creator of the structure or guideline decides upon which aspects the learners should focus. The existence of this kind of structure may influence learners' perception of a task (Zhang & Norman, 1994), and this may in turn influence the learners' ability to solve the task. When provided with a beneficial representation, learners may perceive the problem in a different manner, enabling them to deal with its content more swiftly (Zhang & Norman, 1994). Their studies showed that learners experience benefits to learning if they receive a supportive task structure (Zhang, 1997; Zhang & Norman, 1994). This mechanism can be used for providing instructional support for the learners.

INSTRUCTIONAL SUPPORT BY EXTERNAL REPRESENTATIONS

When external representations are applied as a means of instructional support, they are mainly directed towards the conceptual level of a task. They aim at facilitating learners' understanding of a particular problem. For this purpose, content specific facilitation highlights central characteristics of the learning material by representing important content structures. Such prestructuring of the shared screen can make important task characteristics salient and can thereby function as a representational guide to learners' content specific negotiations (Suthers & Hundhausen, 2003). The broad variety of structures for external representation (Löhner & van Joulingen, 2001) lead to a wide variety of facilitation methods, differing in the degree of freedom that learners have, and in the degree of support they receive when working with them. In general, one can distinguish between three different classes of support: *simulations*, *conceptualisation tools*, and *templates*. All three classes have the fact that learners interact with the external representations and that external representations guide the learning processes in common.

Simulations (e.g., Roschelle & Teasley, 1995) allow learners to simulate scientific processes; learners work with simulation software, which models the respective processes dependent on specific parameters. Roschelle and Teasley (1995), for example, provided learners an 'envisioning machine'. This machine simulated Newton's Law in respect to the concepts of velocity and acceleration. Learners were able to modify the vectors of velocity and acceleration in the Newtonian world and could directly see the effects of their changes within the simulation. Thus, the general principle of simulations is that an external representation provides parameters for learners to modify. Based on these modifications, the learners get direct feedback on this change within the simulation. In this way, simulations aim at understanding the influence of particular factors on a whole (simulated) system.

In contrast to simulations, **conceptualisation tools** allow the modeling of relations by the learners. In this case, the tool provides objects of different styles and different relations important for the content area and the learners can create their own representation of the structure of a particular content (Fischer et al., 2002; Suthers & Hundhausen, 2003). Fischer et al. (2002) presented a tool for structured visualisation. Learners were given the assignment to make a lesson plan for a class and to take different motivational issues into consideration. The tool provided cards for the learners to visualise lesson elements and other cards to visualise motivational aspects. Furthermore, they had different kind of lines to visualise relations between the lesson elements and the motivational issues. The tool enabled learners to get an image of the pros and cons of different lesson elements and to decide which lesson elements to use. Thus, conceptualisation tools aim at deeper understanding of structures within particular content area.

Templates prestructure a content domain (Brooks & Dansereau, 1983; Ertl et al., 2006; Suthers & Hundhausen, 2003). They are mainly in the style of tables and provide categories, which are particularly important for content specific negotiation. Learners fill the empty spaces in the template and thereby focus on important categories (see Table 1). However, learners cannot change the structure of the template and model new relations. Therefore, templates aim to help learners to understand important aspects of a content area. In the following, this article provides an example of a content scheme, which is related to the class of templates, to illustrate the possible application of external representations for computer supported collaborative learning.

CONTENT SCHEMES

Content schemes provide templates for learners that comprise of placeholders for important aspects. They often provide tabular structures (e.g., Brooks & Dansereau, 1983; Ertl, Reiserer, & Mandl, 2005; Suthers & Hundhausen, 2003). This structure of the scheme remains salient during collaboration and focuses learners on the aspects introduced by the placeholders (Suthers & Hundhausen, 2003). This style of guidance can be important for promoting important aspects of a task implicitly, which means that learners use this structure without being directly told to do so. Therefore, such

Table 1. Content scheme from Ertl et al. (2005)

Theoretical concepts	**Evidence**
What are the core concepts of the theory?	How was the theory examined?
What are the most important statements of the theory?	Which findings support the theory?
Consequences	**Individual opinion**
Which pedagogical interventions can be derived from the theory?	What do we like about the theory? What do we not like?
Which limitations of pedagogical interventions are set by the theory?	Which of our own experiences confirm the theory? Which of your own experiences contradict the theory?

structures are particularly suited for distance education because there is usually little direct contact between instructors and learners. Until recently, the effects of such representational structures were often studied within the context of individuals (Brooks & Dansereau, 1983; Kotovsky & Fallside, 1989; Kotovsky, Hayes, & Simon, 1985; Larkin, 1989; Zhang, 1997; Zhang & Norman, 1994). However, during the last decade studies emerged about the use of representational guidance in computer supported collaborative learning (Ertl et al., 2006; Fischer et al., 2002; Suthers & Hundhausen, 2003). Results of these studies show that content schemes also have beneficial effects in collaboration.

Ertl et al. (2005) presented learners with a content scheme for collaborative theory teaching. It comprised of the categories of theory, evidence, and elaboration (see table 1). In their study, two learners acquired knowledge about different theories individually so that each learner had detailed knowledge about one particular theory. The learners' collaborative task was to mutually teach the learning partner the theory that they had previously learned. During their collaboration, they worked with the content scheme (see Table 1) which guided them through the process of theory teaching. They used it for dealing with the aspects of theory, evidence, and personal elaboration (which comprised of the consequences of the theory and the individual opinion).

Ertl et al. (2005) could show that the scheme focused learners particularly on the categories of evidence and elaborations. These were neglected by learners without scheme (Ertl et al., 2005). In a further study, they were able to show effects of a content scheme for collaborative problem solving (Ertl, Kopp, & Mandl, 2006). Also this content scheme focused learners on categories, which were overlooked without, and encouraged them to take these categories into consideration. Suthers and Hundhausen (2003) reported similar results with respect to a tabular template. In their study, learners with a template provided more concepts between theoretical concepts and evidence.

FACILITATION AND LEARNERS' PREREQUISITES

External representations have proven to be beneficial for computer supported collaborative learning in several studies. They offer quite a lot of possibilities and opportunities for learners' facilitation. However, not all of the opportunities that facilitation methods offer may have the desired effects (Weinberger, Reiserer, Ertl, Fischer, & Mandl, 2005). They may be dependent upon learners' individual prerequisites, for example, prior knowledge (Ertl & Mandl, 2006; Shapiro, 2004), their cognitive abilities (Sweller, van Merrienboer, & Paas, 1998), or motivational aspects of the learning scenario (Deci & Ryan, 1992). This is particularly important for support methods using external representations as they may offer complex tools. These may require quite skilled learners with a high amount of prior knowledge. If such facilitation methods offer many freedoms to the learners, they may be too complex for beneficial activities (Dobson, 1999). When applying such complex facilitation methods, they may exceed learners' cognitive abilities and result in cognitive overload (Sweller et al., 1998). Such effects may negate the benefits of facilitation. Consequently, complex methods, which have a high degree of freedom, may be best suited for highly experienced learners, while rather restricted, highly structured methods may provide most benefits for inexperienced beginners.

Yet if facilitation methods are simplifying a task too much, this could result in a reduction of learners' mental activities. In such situations, learners may also have lower learning outcomes (e.g., Salomon, 1984) because learners' cognitive activities are the key to understanding. Therefore, facilitation methods should aim for the evocation of beneficial mental activities. It may be advantageous for complex tasks to make them easier and to reduce complexity for the learners to increase their understanding of the subject. In contrast, it may be more suited for simple tasks that facilitation methods make these tasks more difficult to evoke increased mental activity in order to improve learning outcomes (Reiser, 2002).

CONCLUSIONS

External representations can be a suitable means for the facilitation of computer supported collaborative learning. They offer a broad variety of styles and can be applied to several different content domains because they are content-specific. However, this has the consequence that the results may be difficult to generalise. A simulation about Newton's Law is hardly applicable to thermodynamics and a tool for structured visualisation may have peculiarities for different content domains. De Jong, Ainsworth, Dobson, van der Hulst, Levonen, Reimann, et al. (1998) describe this as the specificity of external representations. External representations which have a high degree of specificity may lack in generalisability and rather unspecific and generalisable tools may have the advantage of being broadly applicable. However, learners may have the skills to adapt them to their particular needs and this may require highly skilled learners (Dobson, 1999).

The main advantage of external representations for the facilitation of computer supported collaborative learning lies in their power to guide learners with their permanent display through their learning process (Ertl et al., 2006; Suthers & Hundhausen, 2003). This offers the chance to improve collaborative learning outcomes using a particular information technology implementation. Consequently, external representations can show their power particularly in distance learning scenarios, which usually have quite restricted instructor-learner contact.

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KEY TERMS

Cognitive Overload: Caused by excessive demands on a learner's mental abilities and can limit their capacity to learn and apply knowledge.

Collaboration: Tight working together with a strong commitment of collaboration partners.

Collaborative Learning: Method of learning by which a group of learners collaborate to achieve improved learning results.

Content Scheme: A content-specific representation of the structure of a particular topic.

External Representation: A material display of knowledge and information which may include facts but also procedures and structures.

Instructional Design: The didactical rationale for a learning scenario which includes instructional elements as well.

Prior Knowledge: Knowledge that the learner possesses about the relevant topic before the collaborative learning phase begins.

Videoconferencing: Users use Web cams and headsets to have audio-visual conversation via Internet. Videoconferencing is often combined with the use of a shared application to enable users to work collaboratively with the same software tool.