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Discussion

Instructional interventions to enhance collaboration in powerful learning environments

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Abstract

The general aim of the contributions to this special issue was to foster learning in computer supported collaborative learning environments by designing instructional interventions that enhance collaboration between learners. Scripts and external representations were used as instructional interventions to support social and cognitive processes, respectively, during collaborative learning. Although, the interventions enhanced these social and cognitive processes, beneficial effects on learning outcomes were not always found. This discussion uses cognitive load theory, particularly the expertise reversal effect, to explain these results. It is concluded that the principles from this theory which pertains to individual learning, show great promise for the design of collaborative learning environments.
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1. Introduction

Modern competency-based curricula increasingly often use powerful learning environments (PLEs), which are rich in information resources and learning materials (e.g., simulations, texts, auditory fragments, animations). PLEs are supposed to stimulate active learning that is characterized by the notion that knowledge is

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constructed by learners based on their social (i.e., collaboration) and cognitive (i.e., problem solving; self-regulation) activities. PLEs situate learning in realistic contexts (Brown, Collins, & Duguid, 1989) to facilitate transfer of acquired knowledge and skills beyond the school context. Moreover, learning materials are used that are representative of real-life problems (Spiro, Coulson, Feltovich, & Anderson, 1988). The articles by De Jong, Kollöffel, van der Meijden, Kleine Staarman and Janssen [1] and Van Joolingen, de Jong, Lazonder, Savelsbergh and Manlove, in which learners were presented with a PLE that allows them to regulate their own learning in collaboration with other learners, show that this is not a guarantee for productive collaboration in the sense that higher learning outcomes are achieved.

Self-regulated learning leads to higher learning outcomes (Zimmerman, 2002), but most learners have difficulty self-regulating their own learning behavior (De Jong et al.; Hofer, Yu, & Pintrich, 1998). As reported, De Jong et al. found that elementary school and high school level learners in both a traditional individual learning setting and a collaborative one (i.e., Active Worlds® and Knowledge Forum) hardly orient themselves toward possible learning goals and do not activate prior knowledge before carrying out a learning task. Van Joolingen et al. posited that high task complexity can be an obstacle to university level learners' self-regulation and conclude that additional support is necessary to help learners become *active* learners. They propose collaboration as a means to promote self-regulation of a learning task.

Van Joolingen et al. state that working in dyads results in more self-regulating activities than working individually. However, the productivity of the collaboration that leads to higher learning outcomes, depends on the quality of the interaction process (Van Drie, van Boxtel, Jaspers, & Kanselaar). Similarly, although multidisciplinary teams can potentially arrive at better solutions to highly complex problems by a synthesis of multiple perspectives, their productivity is threatened by a lack of common ground among team members. (Beers, Boshuizen, Kirschner, & Gijselaers). Moreover, the fact that team members often do not know each other well, may lead to feelings of uncertainty among team members, which stands in the way of a productive discourse and collaboration (Mäkitalo, Weinberger, Häkkinen, Järvelä, & Fischer). The articles in this special issue propose several instructional interventions that overcome these problems and, thereby, enable productive collaboration.

2. Type and aim of the instructional interventions

Every contribution uses an *electronic* PLE equipped with tools such as a chat, a shared workspace, et cetera that enable collaboration. Two types of instructional interventions were used in the contributions: scripts or instructions prescribing how team members should interact, collaborate and solve problems (Beers et al., Makitälo et al.) and external representations or spatially organized pictures and/or

[1] To make this discussion more readable the authors have chosen not to constantly add the words "this issue" to references to the articles in this issue.

text depicting hierarchical and/or coordinate relations (De Westelinck, Valcke, Decraene & Kirschner; Van Drie et al.). These scripts and external representations are designed to support social and/or cognitive processes during collaborative learning.

Kreijns, Kirschner, & Jochems (2002, 2003) state that social interaction is a key element in collaborative learning. Social interaction that creates social cohesion is necessary for socio-emotional processes that underlie group forming and group dynamics, as well as cognitive processes to occur. A sense of community, trust and belonging in a group facilitates learning. In electronic PLEs group members do not always meet each other face to face which could impede social interaction. So, in these environments special care should be taken to stimulate social interaction. The importance of social interaction in collaborative learning is acknowledged by De Jong et al., Van Joolingen et al., and Makitälo et al.

Van Joolingen et al. and Kreijns et al. (2002, 2003) propose a socially oriented tool to enhance social interaction in electronic PLEs. This tool is directed at promoting social awareness, that is, learners perceive the presence of other learners which gives them the opportunity to communicate with them. Showing who is online, were he or she is in the electronic PLE, or his or her history in it, creates a sense of proximity in a group which leads to social interaction. In Active Worlds® (De Jong et al.) a learner's presence is visible through avatars (i.e., animated 3D characters) and a chat function allows for synchronous communication.

The contribution of Makitälo et al. concerns the reduction of uncertainty (i.e., a social aspect) that could arise when learners collaborate only in electronic PLEs and never meet face to face. They differentiate between uncertainty on the socio-emotional level (i.e., uncertainty caused by the absence of immediate feedback or non-verbal cues in electronic PLEs) and on the epistemic level (i.e., uncertainty about the content quality of their contributions) and focus on this latter level. They choose a cognitively oriented script that increases the amount of discourse (i.e., social interaction) to reduce 'epistemic' uncertainty. This script provides instructions to help triads interact, collaborate and solve problems by providing self-explanation prompts (i.e., content related questions). According to uncertainty reduction theory (Berger & Calabrese, 1975) these prompts lower uncertainty on an epistemic level, which increases the amount of discourse and, thus, interaction and collaboration with beneficial effects on problem solving.

Beers et al., Van Drie et al. and De Westelinck et al. all use instructional interventions to support cognitive processes (i.e., problem solving, knowledge building) during collaborative learning. These contributions use face to face settings' which support social interaction. In such settings uncertainty on the socio-emotional level is not an issue. The script of Beers et al. provides instructions to help multi-disciplinary triads to interact by providing them the order in which they have to negotiate common ground, and to collaborate and solve a complex problem by providing them the steps that have to be taken to reach common ground (i.e., add a contribution, verify it, clarify it, accept or reject it and take a position). This script enables triads to reach common ground which is believed to have beneficial effects on the problem solving process.

The external representations of Van Drie et al. are used to directly support domain-specific reasoning in history. A causal diagram and a list are used to support argumentation while a matrix is used to support both argumentation and historical change. Dyads are asked to construct the external representations themselves which is believed to have beneficial effects on elaboration and co-construction. It is assumed that these external representations enable the dyads to grasp the content which, in turn, has beneficial effects on performance. The external representations of De Westelinck et al. are used to support domain-specific knowledge building in the social sciences from text. Concept map-like graphic organizers in which cause–effect relationships, inter-dependencies or hierarchies are depicted are used to support individual learning from text.

3. Presentation of the instructional interventions

Van Bruggen, Kirschner, & Jochems (2000) have shown that instructional interventions, such as scripts and external representations, though expected to facilitate learning actually can cause a cognitive overload and hinder learning. According to cognitive load theory (Paas, Renkl, & Sweller, 2003a, 2004) the cognitive load a learner experiences during learning is caused by a combination of the learning task and the design of the content of the instruction in the (electronic) PLE. The complexity of the learning task caused by the number of information elements together with the inter-activity between the elements yields intrinsic cognitive load. The design of the content and the learning activities required of the learners yields either ineffective cognitive load if it is unnecessary and interferes with learning (e.g., mentally integrating different information sources, such as, pictures and explanatory text in order to understand the learning material, or weak-method problem solving) or effective cognitive load if it is necessary and enhances learning (e.g., high variability of practice problems, or self-explanations). Intrinsic, ineffective, and effective load are considered additive in that, taken together, the total load cannot exceed the memory resources available if learning is to occur. With a given intrinsic cognitive load, well-designed content minimizes ineffective cognitive load and optimizes effective cognitive load within the threshold of the totally available cognitive capacity (for an overview see, Paas, Tuovinen, Tabbers, & van Gerven, 2003b).

In their contribution De Westelinck et al. describe three principles to reduce ineffective cognitive load: the spatial contiguity principle (i.e., the split attention effect; Chandler & Sweller, 1992), the modality principle (i.e., the modality effect; Mousavi, Low, & Sweller, 1995), and the redundancy principle (i.e., the redundancy effect; Kalyuga, Chandler, & Sweller, 2000). The *spatial contiguity principle* aims at reducing ineffective cognitive load by *physically* integrating two sources of information that are unintelligible by themselves such as a figure and its explanatory text. This way the learner does not have to *mentally* integrate these sources in order to understand them because this is already accomplished through the presentation mode. The *modality principle* aims at reducing ineffective cognitive load by 'expanding' working memory by making use of a part of working memory dedicated to auditory information. Presenting information in two modalities – visually and auditorily – enables learners to process the information with the part of working memory dedicated to visual material and the part dedicated to auditory information. The *redundancy principle* aims at reducing ineffective cognitive load by avoiding presenting the same information twice but in a different form, for example, animation with text and narration. These principles are well-researched and have been proven to have beneficial effects on learning outcomes (for overviews see Sweller, 1999; Sweller, Van Merriënboer, & Paas, 1998).

The measures taken by De Westelinck et al. to reduce ineffective cognitive load did not result in better learning outcomes. In the case of the spatial contiguity principle, learners who received the external representation separated from the text even performed better than those who received these information resources integrated. This could be explained by the fact that the information sources used by De Westelinck et al. are intelligible by themselves, which could be inferred from the authors' statement that they did their best to represent '...the structural relationships in the body of knowledge...'. If this is the case, presenting the external representations along with the text leads to a redundancy effect, which could explain that better learning outcomes failed to occur.

An important learner characteristic influencing the balance between intrinsic, ineffective, and effective cognitive load is *expertise*. Expertise is acquired through experiences that enable learners to acquire domain-specific knowledge and skills (Ericsson & Lehmann, 1996). Kalyuga, Ayres, & Chandler (2003) have shown that knowledge of the learner's level of expertise is of importance for instructional designers to be able to categorize information and activities as intrinsic, ineffective, or effective, and to predict learning outcomes. A cognitive load that is effective for a novice may be ineffective for an expert. In other words, information that is relevant to the process of schema construction for a beginning learner may interfere with this process for a more advanced learner. This so-called *expertise reversal effect* may, for instance, be found with an instructional intervention like learner support. While imposing an effective load on inexperienced learners it will cause an ineffective cognitive load on more experienced learners. For the more experienced learners the support will impede learning. To anticipate this effect, instructional interventions should diminish learner support with increasing expertise enabling learners to allocate the available cognitive capacity to relevant processes and information and foster learning outcomes. Although, the expertise reversal effect has only been studied in an individual learning setting it is possible that this effect will also appear with increasing expertise in *groups*.

There are two ways to diminish support to groups with increasing expertise. First, support can be faded as expertise increases during problem solving or carrying out a learning task. This means that increasingly diminished detailed support is presented to the groups as their expertise increases. When script usage is decreased, instructions on how to interact, collaborate and solve problems could be functionally decreased until no instruction is given at all. When external representations are used they could become gradually less detailed and/or more general as expertise increases. Second, group control over support can be augmented when expertise increases. In other words, the groups are given increasing control over when and what kind of support they want to use. Inexperienced groups are coerced to adhere to a script or to use external representations but experienced groups are free to adhere to a script or to use external representations.

Beers et al. varied the level of coercion used to support inexperienced multi-disciplinary triads to adhere to the script. Three types of triads were formed, high coercion triads, low coercion triads and no coercion triads. As expected from cognitive load theory, the triads using high coercion scripts reached the most common ground. This can be interpreted as an indication that principles from cognitive load theory that were found for individual learning may also be applicable to collaborative learning. Apparently, this script helped team members not to get lost in talking at cross-purposes (i.e., a reduction in ineffective cognitive load) and to focus on interactions that were beneficial for learning (i.e., an increase in effective cognitive load). This line of reasoning can be argued to have consequences for the instructional interventions proposed by Van Joolingen et al., Makitälo et al., and Van Drie et al.

In Co-Lab (van Joolingen et al.) a number of support tools, both social and cognitive, are available to the learners but they are never coerced to use them. It is possible that inexperienced learners in Co-Lab need this coercion to protect them from being overloaded by this electronic PLE and the complex problems in it. As van Joolingen et al. point out themselves, '...task complexity can get in the way of learners' spontaneous use of self-regulatory skills...', the same could be true for learners' spontaneous online tool use.

On the other hand, in the contributions of Makitälo et al. and Van Drie et al. the groups were coerced to adhere to either the script or the external representations. Although, the script and the external representations yielded the expected outcomes, indicating an increase in the amount of discourse and better argumentation and insight with regard to historical change, respectively, there was no evidence for better learning. Possibly, the coerced adherence to instructional interventions, without taking increasing learner expertise (expertise reversal effect) into account, might have led to an increase in ineffective cognitive load and interfered with learning.

4. Conclusion

To conclude, this issue's contributions describe instructional interventions to enhance collaborative processes, such as grounding, discourse, argumentation, with the ultimate goal of achieving better learning outcomes. Although, the interventions successfully supported these cognitive processes during collaboration, beneficial effects on learning were not always found. This could be explained in terms of cognitive load theory. Research in this area shows that individual learners react differently to instructional interventions as their expertise increases. This implies that during the learning task(s), the instructional interventions should change in line with the learners increase of expertise. When the instructional interventions are not adapted to a learner's level of expertise, this hampers the learning that might have occurred in the case in the contributions of Makitälo et al. and Van Drie et al. Of course, it still remains to be resolved whether the principles from cognitive load theory that pertain to individual learning could be applied to collaborative learning. This is a very interesting topic for future research that aims at designing instructional interventions that enhance productive collaboration.

Cognitive load theory and the field of collaborative learning could both benefit from research along these lines. Researching whether the design guidelines from cognitive load theory are also applicable to collaborative learning could be an important extension of this theory and could result in new set of design guidelines on how to keep the balance between intrinsic, ineffective and effective cognitive load during collaborative learning. The introduction of cognitive load as a measure in collaborative learning, on the other hand, could provide more insight in the mental effort learners invest during collaboration and the associated performance. An efficiency measure could be calculated based on both mental effort and performance (see Paas & van Merriënboer, 1993). The lower the invested mental effort and the higher the performance, the more efficient the collaboration process will be. The efficiency measure could be used to compare the efficiency of individual learning and collaborative learning. In this way, situations could be identified in which collaborative learning is called for and situations in which individual learning is most appropriate.

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