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Citation for published version (APA):

Wang, M., Kirschner, P. A., Spector, J. M., & Ge, X. (2018). Computer-Based Learning Environments for Deeper Learning in Problem-Solving Contexts. *Computers in Human Behavior*, *87*, 403-405. https://doi.org/10.1016/j.chb.2018.06.026

DOI:
10.1016/j.chb.2018.06.026

Document status and date:
Published: 01/10/2018

Document Version:
Publisher's PDF, also known as Version of record

Document license:
Taverne

Please check the document version of this publication:

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
- The final author version and the galley proof are versions of the publication after peer review.
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Computers in Human Behavior 87 (2018) 403–405

Contents lists available at ScienceDirect

Computers in Human Behavior

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

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1. Introduction

Learning through problem solving has been widely promoted in educational practice, and more recently in computer-based learning environments (CBLEs). However, effective learning through problem solving is difficult to realize since learning in such contexts often involves complex cognitive processes that are inaccessible to novices. Many students tend to engage in surface-level experience rather than meaningful learning (Wang, Kirschner, & Bridges, 2016) when they are not provided with necessary support.

It has been noted that open-ended exploration in complex problem situations imposes a heavy cognitive load on learners (Kirschner, Sweller, & Clark, 2006), and the use of scaffolding – often with the aid of some form of instruction – is important, if not essential to learning with complex problems (Hmelo-Silver, Duncan, & Chinn, 2007; Ge & Land, 2003). This echoes to a certain extent the cognitive apprenticeship model, which claims that carrying out a complex task usually involves implicit processes, and it is crucial to make such processes explicit and visible for novices to observe and practice with necessary help (Collins, Brown, & Holum, 1991). While research has offered a foundation for understanding learning in inquiry and problem-solving contexts, the design of appropriate CBLEs to support such learning and integrating technology in educational practice are often associated with sophisticated and ambitious reform for which the implementation process is uncertain or ill-specified. Although technology-enhanced learning with real-world problems and authentic tasks has been increasingly promoted, there is concern about its weaknesses in learning and instructional design with, at best, mixed learning outcomes. The concern is also related to the use of traditional assessment approaches, which may not be sensitive to learning in problem-solving contexts (Spector 2006; Gijbels, Dochy, van den Bossche, & Segers 2005).

This special issue attempts to examine how deeper learning in problem-solving contexts can be empowered by effective design of CBLEs along with appropriate analysis of learning in such environments. Deeper learning is supported by relevant learning approaches or strategies that allow learners to manage the complexity and key challenges of learning (most on cognitive aspects) to sustain motivation and achieve a high level of understanding and performance. While deeper learning is often accompanied by intrinsic motivation, cognitive approaches play an important role in helping learners persist through challenges and setbacks to achieve desired learning outcomes and guard against a loss of motivation through failure. Cognitive approaches to fostering deeper learning in problem-solving contexts have focused on making the tacit aspects of complex tasks and related knowledge visible and accessible to learners for effective thinking, action and reflection, for example by externalizing the complex process of solving a problem, presenting the knowledge underlying the problem-solving process, connecting new ideas with prior knowledge, making knowledge evolve by resolving conflict views, and combining discrete pieces of knowledge into a coherent whole (Wang, Derry, & Ge, 2017).

This special issue provides a platform for researchers to present their findings and efforts, offering insights into how deeper learning in problem-solving contexts can be fostered with the support of technology from different perspectives. Its focus is on investigating the challenges encountered by learners in problem-solving contexts and addressing them through effective design of CBLEs and appropriate analysis of learning in such contexts.

2. Preview of papers

In the first paper "Reflective learning with complex problems in a visualization-based learning environment with expert support", Minhong Wang, Bei Yuan, Paul A. Kirschner, Andre W. Kushniruk and Jun Peng (2018) explored a computer-based learning approach that helped medical students develop expert-like performance in glaucoma diagnosis. The approach features a visualization-based learning environment that allows learners to review their problem-solving process and view the difference between their performance and that of the expert in a visual format for effective thinking and reflection (Yuan, Wang, Kushniruk, & Peng, 2017). This study examined the effects of the approach by comparing to visualization-based learning without revealing the expert-novice difference. The results demonstrated that revealing the expert-novice difference for reflection by learners made the visualization-based learning environment more effective in improving learners' problem-solving performance, allowing them to construct knowledge from task experience, and making them feel confident when working with complex problems.

Problem-based learning (PBL) has been widely promoted in educational practice especially medical education. In PBL, students are expected to adopt self-regulated learning strategies to engage in deeper learning with authentic problems. However, students may experience difficulties in adopting self-regulated learning strategies especially when they feel uncertain about what they should learn in a PBL environment. Sanne F. E. Rovers, Geraldine Clarebout, Hans H. C. M. Savelberg, and Jeroen J. G. van Merriënboer (2018) investigated this issue in the second paper entitled "Improving student expectations of learning in a problem-based environment". The study proposed to use a workshop to align students' expectations of the PBL environment with those formulated by the university. The results revealed the benefit of the workshop in improving students' intentions to take responsibility for their own learning in the PBL context, although no significant effect on improving students' use of self-regulated learning strategies.

The third paper "Deeper learning in collaborative concept mapping: A mixed methods study of conflict resolution" by Weichao Chen, Carla

https://doi.org/10.1016/j.chb.2018.06.026

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Allen, and David Jonassen (2018) investigated deeper learning in the context of collaborative concept mapping. Healthcare students engaged in collaborative concept mapping to solve an authentic problem in triads. The study examined the effects of learners' conflict resolution on their deeper learning as measured by knowledge convergence, i.e., the similarity between team members' post-collaboration knowledge represented in concept maps derived from collaborative concept mapping. Contrary to prior research findings, increased conflict negotiation behaviors by an individual resulted in fewer similarities between his or her post-collaboration map and other members' maps. It was also found that interaction strategies and the challenges experienced by learners in group interaction had influenced knowledge convergence.

Scaffolding has played an important role in fostering deeper learning in problem-solving contexts. However, little research has investigated the role of fading in this context. Andrew A. Tawfik, Victor Law, Xun Ge, Wanli Xing, and Kyung Kim (2018) explored this issue in the fourth paper entitled “The effect of sustained vs. faded scaffolding on students’ argumentation in ill-structured problem solving”. They investigated the effects of fading question prompts on argumentation as junior business students were given two fading schedules: sustained scaffold schedule, and faded scaffold schedule. The results indicated that scaffolds should not be faded before students have acquired the necessary problem-solving processes and that novices might need a fuller set of scaffolds for a longer period to support their problem-solving performance.

While concept mapping has been widely used to support the communication and in-depth understanding of complex ideas, traditional concept mapping is limited in representing the complex process of applying knowledge to solve problems. Minhong Wang, Bian Wu, Paul A. Kirschner, and J. Michael Spector (2018) discussed this issue in the fifth paper “Using cognitive mapping to foster deeper learning with complex problems in a computer-based environment”. They proposed a computer-based cognitive-mapping approach that extends traditional concept mapping by representing the problem-solving process along with the underlying knowledge in a visual format. They examined the effects of this approach versus a note-taking approach that represents the problem-solving process and the underlying knowledge in verbal text only. Findings showed the advantages of the approach in improving medical students' diagnostic performance, subject knowledge, and motivation to learn with complex problems.

The sixth paper “Supports for deeper learning of inquiry-based ecosystem science in virtual environments - Comparing virtual and physical concept mapping” by Shari J. Metcalf, Joseph M. Reilly, Amy M. Kamarainen, Jeffrey King, Tina A. Grotzer, and Chris Dede (2018) presented an inquiry-based middle school curriculum for deeper learning of ecosystem science. The study examined the effects of computer-based scaffolded concept mapping versus paper-based flexible concept mapping on student thinking and reasoning in a virtual pond ecosystem. The results revealed the benefit of the computer-based concept mapping tool in helping middle school students to develop in-depth understanding of complex causalities in a dynamic system by allowing students to identify more causal relationships and represent them in a more consistent way.

In the seventh paper “Investigating children's deep learning of the tree life cycle using mobile technologies,” Gi Woong Choi, Susan M. Land, and Heather Toomey Zimmerman (2018) designed a mobile application to support children's problem-solving activities in an outdoor summer camp setting. They analyzed how children used problem-solving strategies to identify and capture the tree cycle. They found that with the support of external representation provided via mobile tablets, students engaged in deeper learning in the outdoor setting by active use of problem-solving strategies, coordination with peers, and making decisions throughout learning activities.

In the eighth and final paper of the special issue “Scientific discourse of citizen scientists: Models as a boundary object for collaborative problem solving,” Joey Huang, Cindy E. Hmelo-Silver, Rebecca Jordan, Steven Gray, Troy Frensley, Greg Newman, and Marc Stern (2018) examined the nature of scientific discourse among participants as they used an online collaborative modeling tool to facilitate thinking, reasoning, and discussions in two citizen science projects. The results showed the effects of the modeling tool in engaging participants and facilitators in group discussions and collaborative problem solving and in shifting the discussions from bottom-up level to top-down level throughout the process.

3. Conclusion

Learning through problem solving is much more easily advocated than accomplished. It is more important than ever in today’s rapidly changing world, where learners have more exposure to authentic experience and are expected to deal with more sophisticated real-world problems. While emerging learning technologies have substantially expanded the opportunities for learning through problem-solving, it is critical to investigate the challenges experienced by learners in such contexts and examine how such challenges can be resolved by effective design and analysis of learning through the use of instructional scaffolds, cognitive tools, and direct instructional approaches to enhance problem solving in CBLEs. We hope this special issue will advance research and development and foster further interest in empowering deeper learning in problem-solving contexts with the support of technology.

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