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Guest Editorial: Fostering Deep Learning in Problem-Solving Contexts with the Support of Technology

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Introduction

Learning and cognition occur in physical and social contexts where knowledge is created and applied, as claimed by situated learning theories (Brown, Collins, & Duguid, 1989; Lave & Wenger, 1991). Knowledge is assumed to be better constructed through interaction with problem-oriented, socially situated environments. Accordingly, learning through problem solving in real-world situations, especially with ill-structured problems (Jonassen, 1997) and authentic whole tasks (van Merriënboer & Kirschner, 2013), has become the central aspect of educational practice. The literature has shown the promising effects of problem-oriented learning in helping students to develop critical thinking and problem-solving skills as well as consolidate and extend subject-matter knowledge. Meanwhile, researchers have reported inconclusive and inconsistent findings on the superiority of problem-oriented learning over conventional instructions (Dochy, Segers, van den Bossche, & Gijbels, 2003), mainly in systematic construction of subject-matter knowledge and the development of efficient reasoning process (Coderre, Mandin, Harasym, & Fick, 2003; Patel, Yoskowitz, Arocha, & Shortliffe, 2009).

Given the constraints of classroom settings in enabling situated learning, technology-supported learning environments have been increasingly explored to support learning with real-world problems and authentic tasks in blended environments. Virtual worlds, simulations, and web-based systems have been increasingly employed to expand the opportunities to learn in authentic contexts (Dede, 2009; Derry, Levin, & Schauble, 1995; Linn, 2000). Technology-supported learning environments have shown their advantages in affording flexible access to information and learning resources, on-demand delivery of learning programs, flexible communication and social interaction, effective data processing and other operations, multimedia representations, and more importantly computer-based learning support.

However, effective learning through problem solving is difficult to realize in both classroom and technology-mediated settings. Solving a real-world problem often involves a sophisticated process of understanding the problem, linking abstract knowledge to problem information, and applying relevant methods and strategies to solve the problem. Such a complex process can generate a heavy cognitive load for learners (Kirschner, Sweller, & Clark, 2006), although the complexity of the learning process is often overlooked by instructors or experts, as for them many of the requisite processes have become largely automatic or subconscious with experience. As a result of their limited abilities to deal with complex problem-solving processes, many learners tend to engage in surface rather than deep learning experience that enables them to achieve desired learning outcomes (Wang, Kirschner, & Bridges, 2016).

Deep learning is characterized by a high level of engagement in learning, driven by intrinsic motivation and more importantly, supported by relevant learning approaches or strategies that allow learners to manage complexity and key challenges (most on cognitive aspects) to sustain engagement and achieve a high level of understanding and performance. While deep learning is driven by intrinsic motivation (Biggs, 1993), cognitive approaches are crucial for helping learners persist through challenges and setbacks in to achieve desired learning outcomes. Cognitive approaches to fostering deep learning in problem-solving contexts are associated with multiple issues involving externalizing the tacit aspects of complex tasks for effective thinking, action, and reflection; relating new ideas with prior knowledge and experience for effective construction of knowledge from practice; converging knowledge by resolving conflicts in social contexts; and combining discrete pieces of knowledge into a coherent whole (Chin & Brown, 2000; Entwistle, 2000).

Making the tacit aspects of complex problem-solving tasks explicit and accessible to learners is related to scaffolding, which has been increasingly recognized as important part of learning in problem-solving contexts (Hmelo-Silver, Duncan, & Chinn, 2007). For example, prompts are used to bring learners' attention to important issues during an ill-structured problem-solving task (Ge & Land, 2003); a complex problem-solving task is decomposed into a set of main actions or key questions to help learners recognize the important goals to pursue during the task (Reiser, 2004). Recent research has highlighted the importance of making thinking visible in complex problem or task situations (Linn, 2000). Learners' active construction of external representations related to the solution of a problem has received increased attention. For example, causal maps representing the relationship of cause and effect (Slof, Erkens, Kirschner, Janssen, & Jaspers, 2012), evidence maps linking evidence with claims or hypotheses (Suthers, Vatrapu, Medina, Joseph, & Dwyer, 2008), and integrated cognitive maps connecting problem-solving and knowledge-construction processes (Wang, Wu, Kinshuk, Chen, & Spector, 2013) have shown their promising effects in improving understanding and performance in problem-solving contexts.

Making complex thinking visible and accessible is important not only for performing a problem-solving task, but also for constructing knowledge from problem-solving experience, converging knowledge by resolving conflicts in social contexts, and combining discrete pieces of knowledge into a coherent whole. Making thinking visible is much more easily advocated than accomplished (Linn, 2000). More research is needed to examine whether and how deep learning can be fostered from multiple perspectives in problem-oriented, socially situated environments.

Learning through problem solving is not new. It is more important than ever in today's rapidly changing world, where learners are required to deal with more sophisticated real-world problems, and have more exposure to authentic experience. While technology has substantially expanded the environment for learning with authentic problems, it is critical to bolster the understanding of multiple challenges of learning in problem-solving contexts, and how such challenges can be resolved by effective design and analysis of learning in technology-supported environments. This special issue aims to provide a platform for researchers to present their findings and efforts that may offer insights into how deep learning in problem-solving contexts can be fostered with the support of technology from different perspectives. The focus is on the challenges of learning in problem-solving contexts, effective design of technology-supported learning environments that address the challenges, and meaningful analysis of learning in such environments.

Preview of papers

In the first paper "EcoXPT: Designing for deeper learning through experimentation in an immersive virtual Ecosystem," Chris Dede, Tina A. Grotzer, Amy Kamarainen and Shari Metcalf present an inquiry-based middle school curriculum that supports blended learning with ecosystem science by utilizing immersive authentic simulation and experimentation together with scaffolding tools in virtual, mixed, and augmented reality environments. Deeper learning in the EcoXPT curriculum is fostered by six strategies, namely case-based instruction, the use of multiple representations of concepts, collaborative learning, apprenticeship-based learning, learning for transfer, and the use of diagnostic assessments.

The second paper "Comparing design constraints to support learning in technology-guided inquiry projects" by Lauren Applebaum, Jonathan Vitale, Libby Gerard and Marcia Linn examined the design and effects of a blended approach to project-based inquiry learning, where hands-on design projects and web-based tools are integrated to improve science learning. Given that many students fail to apply core science principles to their design, web-based models and tools are used to help learners capture such principles during the project. Moreover, a constraint-based goal is imposed on the design project with a view to inducing students' creativity when they work with constraint-based design problems.

In the third paper "Design of a three-dimensional cognitive mapping approach to support inquiry learning," Juanjuan Chen, Minhong Wang, Chris Dede and Tina A. Grotzer examined how a novel three-dimensional cognitive mapping (3DCM) approach makes complex inquiry learning visible and accessible to middle school students, by allowing them to externalize the hypothesizing and reasoning process, subject-matter knowledge, and problem information in a single image for effective thinking, action, and reflection. Using this approach, students at a low academic level acquired more knowledge than either the high-level or medium-level students, thus narrowing the academic gap between low-level, medium-level, and high-level students.

Student prior knowledge of scientific phenomenon is often fragmented and plagued with incompatible and incomplete understanding, but valuable for generating curriculum that encourages deeper understanding of scientific concepts. In the fourth paper "Leveraging students' prior knowledge to adapt science curricula to local context" Lana M. Minshew, Kelly J. Barber-Lester, Sharon J. Derry, and Janice L. Anderson investigated how students' prior knowledge can be leveraged in curriculum design to promote deeper learning in science curricula. The study presents a model-based assessment that elicits the evidence of student understanding of key concepts and relationships relevant to energy and matter in an ecosystem.

The fifth paper "Moving apart and coming together: Discourse, engagement, and deep learning" by Andrea S. Gomoll, Cindy E. Hmelo-Silver, Erin Tolar, Selma Šabanović, and Matthew Francisco investigated how students collaboratively construct and represent shared understanding in a complex, problem-oriented, and authentic learning environment with a robotics design project. The findings reveal the importance of embodied actions of learning in supporting deep and robust engagement in collaborative learning, for example by positioning authority and accountability, directing attention, and providing support for verbal reasoning.

With limited problem-solving capability and practical experience, it is difficult for novices to develop expert-like performance without necessary support. In the sixth paper "Deep learning towards expertise development in a visualization-based learning environment," Bei Yuan, Minhong Wang, Andre W. Kushniruk, and Jun Peng examined the design and effects of a model-based learning approach implemented in a web-based learning environment that allows learners to capture and reflect on their problem-solving process in visual formats as well as identify the gap between their performance and that of the expert for effective reflection and improvement towards expertise development.

In the seventh paper "Deep and surface processing of instructor's feedback in an online course," Kun Huang, Xun Ge, and Victor Law explored the characteristics of deep and surface approaches to learning online students demonstrated in their responses to instructor's qualitative feedback to a multi-stage, ill-structured design project. The findings reveal the patterns of deep and surface learning manifested in individual approaches to addressing feedback, and the influence of learner characteristics such as epistemic beliefs and need for closure on individual approaches. The findings provide insights into feedback strategies for deep learning.

Owing to a lack of opportunities for authentic use of a foreign language, many foreign language students fail to use the target language in a meaningful way. The eighth paper "Investigating the effects of authentic activities on foreign language learning: A design-based research approach" by Ildeniz Ozverir, Ulker Vanci Osam, and Jan Herrington presents the design and analysis of a computer-assisted foreign language learning environment, where task-, problem-, and project-based authentic learning activities were incorporated into a Moodle system containing relevant learning resources and functions for communication and assessment.

In the ninth paper "Visualizing the complex process for deep learning with an authentic programming project" Jun Peng, Minhong Wang, and Demetrios Sampson investigated how the complex process of carrying out an authentic programming project can be made visible and accessible to learners. Implementing project-based learning remains a challenge in programming education since advanced programming strategies are implicit and hard to capture, but critical for programming. This study examined the effects of a visualization-based learning environment that externalizes the complex process of applying advanced programming strategies to design and develop artifacts of authentic programming projects.

Problem-based learning often involves a great deal of information searching and selection, where students need to identify useful information to solve a problem. In the tenth paper "Can students identify the relevant information to solve a problem?" Lishan Zhang, Shengquan Yu, Baoping Li, and Jing Wang explored the design of a computer-based assessment system and used the system to assess elementary school students' ability to select relevant information and search for additional information to solve real-world problems.

The eleventh paper "An eye tracking study of high and low performing students in solving interactive and analytical problems" by Yiling Hu, Bian Wu and Xiaoqing Gu presents an eye-tracking study that investigated the use of different information processing strategies by students in solving analytical and interactive problems. The results also examined the differences among high- and low-performing students in their use of information-processing strategies to solve the two types of problems.

In the last paper of the special issue, Kaushal Kumar Bhagata and J. Michael Spector reviewed prior work on using technology as a formative assessment and feedback tool in learning with complex and ill-structured tasks. Their paper "Formative assessment in complex problem-solving domains: The emerging role of assessment technologies" highlights the role of technology-enabled formative assessment in supporting learning in problem-solving contexts. The paper also gives recommendations for further research on using technology to support formative assessment in complex problem-solving domains.

Conclusion

We conclude by noting that the papers in this special issue are intended to be representative of ongoing research in fostering deep learning in problem-solving contexts with the support of technology. The international scope and breadth of the research is distinctive. We hope this special issue will foster further interest in what we believe will become an area of increasing importance.

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