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Guest Editorial: Special Section on Learning Systems for Science and Technology Education

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Many successful computer-based educational systems have been developed and empirically tested in science and technology domains. A number of these systems are designed to be intelligent in analyzing and understanding learner input and adapting to the students’ level of knowledge. Science and technology domains are well defined and can be described using formal representation. However, deeper understanding of the concepts and principles, and developing problem solving skills such as inquiry and discovery skills in science and technology domains, make the design and implementation of learning environments quite challenging. Students often have difficulties learning these skills; thus, scaffolding mechanisms become an important component of these systems. Furthermore, science knowledge and achievement is a core prerequisite for careers in engineering and technology. Hence, these skills are vital to the well being and continued advancement of society.

However, in spite of the central role that science and technology plays in sustaining and advancing our societies, college enrollment in science and technology has been declining in many European and American countries [1], [2]. Fewer students take science and technology courses and many drop out after initially enrolling in these programs. Research and reviews identify a lack of engagement and motivation in science, starting from the middle school and continuing through post-secondary education [3], [4]. These reviews also point out that computer-based tools are most often used for very basic instruction, such as manipulating data and applying mechanical or algorithmic procedures, and not to teach conceptual understanding of key scientific ideas. Moreover, many assessment tools focus on multiple-choice question answering and short answers, which are not very amenable to gaining a deep understanding of domain concepts and to developing problem solving skills.

Yet computer-based technology can significantly enhance science education and training, as well as shape both what and how people learn. With this special issue of the IEEE Transactions on Learning Technologies (TLT), we present contributions that address education and training in science and technology disciplines using computer-based technology innovations, with a particular emphasis on the development and application of intelligent software that supports conceptual understanding and high-order learning approaches.

This special section includes six contributions. The first four papers focus on specific systems for learning topics in science and technology. Each contribution highlights a unique educational need and describes and argues for technology that has been developed to enable that learning. The systems have all been used and tested in real-world educational settings.

Dragon et al. present Metafora, a software platform to support students in self-regulating their group learning of science and mathematics topics. The authors argue that learning subject matter relies upon the acquisition of critical skills for learning together. To illustrate and emphasize this point, the authors discuss the critical skills underlying learning “how to collaboratively learn”—for instance, distributed leadership and mutual engagement—and refer to this collection of higher-order skills as “Learning to Learn Together” (L2L2). Next, the authors explain how technology can enable and support L2L2. The Metafora system brings together technology for planning, experimentation and exploration (using microworld software), and reflection (using collaborative discussion and argumentation software). The authors describe Metafora as both a pedagogy and platform to promote L2L2. Their approach is illustrated using a scenario built from empirical observation and data logged in a real educational setting.

Bollen and van Joolingen present SimSketch, a system targeted at learning science through sketching and simulating the resulting sketches. The authors advocate a self-guided discovery approach to learning, focusing on having learners acquire subject matter through freely building models and running simulations. They argue for the motivational benefits of this approach. A big challenge in their work is bridging the gap between formal modeling tools and the more conceptual and informal approaches of constructing, evaluating, and revising models. SimSketch allows learners to draw a model by hand, through digitized sketches, and, thus, work in an informal way. Components appearing in the drawings are associated with predefined behavioral features of formal models, allowing learners to then simulate the behavior of a system without having to be skilled in the semantics and syntax of formal modeling approaches.

For information on obtaining reprints of this article, please send e-mail to: lb@computer.org.
Bert Bredeweg is an associate professor with the Theory of Computer Science section, one of the eight research groups within the Informatics Institute at the University of Amsterdam. Dr. Bredeweg researches artificial intelligence and education and focuses on interactive learning environments that enable learners to explore and acquire conceptual knowledge. His research is driven by fundamental questions about computational intelligence and includes themes such as knowledge capture, qualitative reasoning, learning by modeling, cognitive diagnosis, and human-computer interaction. Dr. Bredeweg has a significant number of refereed publications and recently coordinated the international DynaLearn project.

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The guest editors would like to thank the authors for supporting this special section by submitting their contributions and then diligently working through the review process. We believe the papers published in this special section demonstrate the wide variety and scope of opportunities for designing effective learning environments for science and technology. We would also like to thank the reviewers for their important role in providing critical but constructive and objective reviews, which were extremely important in making this a quality special section. In thanking the reviewers, we would like to note that special care was taken in reviewing the papers for which the special section guest editors are coauthors. In particular, the reviews and accept/reject decisions for these papers were handled by Associate Editors who did not have direct connections to the special section. We also want to thank Editor-in-Chief Peter Brusilovsky for his support and effort in bringing this special section to fruition. Finally, we are grateful to the IEEE TLT staff for prodding and poking three very busy researchers in keeping this special section on schedule.

REFERENCES


Bruce M. McLaren is a senior systems scientist in the Human-Computer Interaction Institute at Carnegie Mellon University, Pittsburgh, Pennsylvania, and an adjunct senior researcher with the Center for e-Learning Technology (CeLTech) at Saarland University, Germany. Dr. McLaren has research interests in educational technology, collaborative learning, intelligent tutoring, and artificial intelligence. He has more than 100 publications in peer-reviewed journals, conferences, and workshops. In addition to his research background, Dr. McLaren has over 20 years experience in the commercial sector, applying research ideas to practical problems using artificial intelligence techniques.

Gautam Biswas is a professor of computer science, computer engineering, and engineering management in the Electrical Engineering and Computer Science Department and a senior research scientist in the Institute for Software Integrated Systems (ISIS) at Vanderbilt University. He conducts research in intelligent systems with his primary interests in hybrid modeling, simulation and analysis of complex embedded systems, and their applications to diagnosis, prognosis, and fault-adaptive control. In his research in learning sciences and technology, he is involved in developing simulation-based environments for learning and instruction. The most notable project in this area is the Teachable Agents project, where students learn science by building causal models of natural processes. He has also developed innovative educational data mining techniques for studying students’ learning behaviors and linking them to metacognitive strategies. He has published extensively, and has more than 400 refereed journal and conference publications. He is a senior member of the IEEE.