Pedagogy of Cyber-Physical Experimentation

Introduction by Zacharias C. Zacharia & Ton de Jong

Computer technology has revolutionized the way science experimentation is implemented nowadays in schools. Recent research has revealed a number of unique affordances of cyber-physical laboratories, which improve the learning experience of students at both a cognitive and an affective level. For instance, the use of virtual labs with affordances that could not be provided through physical labs (e.g., provision of representations of conceptual and abstract objects, such as vectors and particles) was found to positively influence science learning. On the other hand, when cyber-physical laboratories are placed within certain pedagogical contexts, especially one involving inquiry, students appear to face a series of problems that relate primarily to addressing the requirements set by the pedagogy. For example, in an inquiry- oriented context, students have difficulty in formulating hypotheses and designing informative and sound experiments. As a result of these difficulties, researchers have placed great emphasis on designing learning environments in which the use of cyber-physical laboratories is accompanied by a series of supportive resources, such as appropriate learning materials (i.e., materials that comply with the pedagogical framing at hand) and adequate guidance tools (e.g., scaffolds, prompts, heuristics). The idea behind such learning environments is to enable the student to have a smooth and productive learning path.

In this section, we deliberately selected work that reports and reflects upon the current, major online learning platforms that support experimentation through virtual and/or remote labs. All of these platforms are of high technical quality and have shown evidence of benefiting learners through their virtual labs, learning materials, and guidance tools. All of these platforms have large-scale usage. In reading each of the chapters in this section, you get a sense of how much the computer and software technology has progressed. You also get a good picture of the potentialities afforded by current online learning platforms. Therefore, there are take-home messages for educators, researchers, designers/developers (e.g., the industry) and practitioners. In particular, each of these individuals could find information in the chapters in this section that points to the new perspectives and challenges of their field. The examples/cases presented in each chapter could also be helpful in this respect. The overall goal is to provide an up-to-date overview of recently developed online learning platforms and to point out the added value that each one could bring to science learning. The section consists of five contributions from researchers who are at the forefront of online learning platform development. In this way, we provide insight into how recent, high-tech platforms are designed, developed, and implemented for learning purposes.

In the contribution, “Advances in PhET Interactive Simulations: Interoperable and accessible”, the authors describe how the PhET Interactive Simulations (phet.colorado.edu) advanced over the years and discuss how recent initiatives, PhET-iO and Accessible PhET Sims, have affected the design and development of the PhET simulations. PhETiO focuses on increasing the interoperability and the level of customization of the PhET simulations, as well as supporting the inclusion of the PhET simulations in interactive e-textbooks and virtual lab notebooks. Moreover, the authors discuss how PhET-iO data could be used for the development of performance tasks. In the case of the second initiative, Accessible PhET Sims, the authors discuss how PhET infrastructure was changed to ensure that all students, including students with disabilities, could have access to PhET simulations.

In the contribution, “Designing virtual laboratories to foster knowledge integration: buoyancy and density”, the authors discuss the iterative process followed for developing an online instructional unit featuring virtual laboratory activities as developed within the WISE platform (wise.berkeley.edu). Specifically, the authors report on a learning activity that focused on investigating how mass and volume relate to the phenomenon of buoyancy. In this context, they evaluated the added value of the activity and the virtual laboratory according to three criteria: enactment of meaningful experiments, proper interpretation of evidence, and discovery of new ideas. Finally, the authors discuss the added value of such an iterative process and how it can affect practice.

In the contribution, “Scaffolding students’ on-line data interpretation during inquiry with Inq-ITS”, the authors present an Inquiry Intelligent Tutoring System (Inq-ITS, www.inqits.com) that includes a variety of interactive simulations and virtual labs for different domains in Physical, Life, and Earth Science. They also present and discuss two affordances of the Inq-ITS. The first aims at supporting teachers with inquiry assessment by providing automatic, formative data, and the second aims at helping students enact inquiry by providing real-time, personalized guidance. Additionally, they have put Inq-ITS to the test. In particular, the authors have examined how scaffolds within Inq-ITS could help students learn skills related to data interpretation and warranting claims. Overall, this work provides a framework for the assessment and scaffolding of these practices.

In the contribution, “Providing pedagogical support for collaborative development of virtual and remote labs: Amrita VLCAP”, the authors present an eLearning platform, Amrita VLCAP (www.olabs.edu.in and vlab.amrita.edu), which is based on a multi-tier architecture that supports collaborative development of cyber-physical materials and carries a number of affordances, such as publishing in various online and print formats, security, auditing, and access controls. The design of the Virtual Labs Collaborative Accessibility Platform (VLCAP) also supports the use of open technologies, provides templates for structuring the pedagogical framing of a learning activity, carries multilingual functionality, and supports sharing virtual labs from multiple geographic locations and securely accessing remote equipment. In showing the potential of the VLCAP for hosting virtual and/or remote labs, the authors present two cases of hosted ICT projects, namely the *Online Labs (OLabs) for school education and Virtual Labs for higher education* project and the *Remote Triggered Wireless Sensor Network Lab* (RT-WSN Lab).

Finally, in the contribution, "Model-based inquiry in computer-supported learning environments: The case of Go-Lab", the authors discuss how model-based inquiry in computer-supported environments could be enacted. To do so, they use the Go-Lab platform (www.golabz.eu), which includes inquiry-based environments for learning (i.e., Inquiry Learning Spaces), virtual and remote laboratories, and scaffolds that support inquiry learning processes, as an example of a learning platform in which model-based inquiry could be implemented. Specifically, the authors present three examples of virtual laboratories with modeling and simulation affordances from the Go-Lab sharing platform, to demonstrate how Go-Lab learning materials, labs and tools could be used for the enactment of model-based inquiry.