Preface

The chapters in this volume are organized into three parts, respectively, with an emphasis on multiple representations used in *learning*, *teaching*, and *assessment,* although each chapter has, to a lesser or greater extent, aspects of all three. The introductory chapter in Part I provides a theoretical basis illustrating by means of a proposed theoretical cube model how multiple representations in biology involving three dimensions (*modes, levels of representations*, and *domain knowledge*) can serve one or more of Ainsworth's (1999) pedagogical functions of multiple external representations (MERs) in supporting learning.

The other chapters in Part I discuss the role of MERs in learning biology. Most of these chapters have a focus on various ways in which students learn biology using MERs and encompass a broad spectrum of major content areas in biology, across the symbolic, submicro, micro, and macro levels along the hierarchical organization in biology, as well as across the different modes of representations encapsulated in different platforms for learning: symbolism (Anderson, Schönborn, du Plessis, Gupthar, and Hull), pictures (Roth and Pozzer-Ardenghi), static visualizations (Eilam), hypermedia (Liu and Hmelo-Silver), and simulations (Yarden and Yarden). Some chapters also emphasize the collaboration of students and teachers in learning with MERs, which has implications for teaching and teacher education (Yarden and Yarden) and can contribute toward developing teaching materials and resolving challenges in teaching (Eilam).

The chapters in Part II examine the implications of using MERs for teaching biology and biology teacher education with each chapter having a major focus on the pedagogy of using MERs in many different instructional strategies and approaches in the major domains of biology. The importance of horizontal and vertical translations across multiple representations in domains of ecology, genetics, and evolution is highlighted by Schönborn and Bögeholz. The focuses in other chapters in Part II range from computer-based modeling for teaching 4th graders (10-year-olds) about evolution (Horwitz) to MERs of genetics in secondary school textbooks (Clément and Castéra) and complex process diagrams in premedical molecular biology (Griffard) and to phylogenetic trees (Halverson and Friedrichsen) and nested systems for teaching about photosynthesis and plant cellular respiration (Schwartz and Brown) in university classrooms. The use of phylogenetic trees in teaching about evolution explained by Halverson and Friedrichsen is vividly illustrated by the real-life example—cited by Wong, Cheng, and Yip—in which genomic sequencing of viral genome led to scientists' success in tracing the source of the Severe Acute Respiratory Syndrome (SARS) virus to bats. Wong et al.'s case study of scientists' research on SARS virus is used in biology and science teacher education for promoting teachers understanding of nature of science.

The chapters in Part III address the assessment of students' understanding of different content areas in biology using different methods and approaches in multi-representational learning environments (e.g., computer-based modeling, computer log files, interviews, conceptual mapping, two-tier tests, microgenetic methods, and others) and along a spectrum of levels. Buckley and Quellmalz illustrates—by way of three learning projects: *Science for Life* (human body systems), *BioLogica* (genetics), and *Calipers* (ecosystems)—how computer-based simulations can be harnessed for both supporting and assessing multiple representational learning of living systems. Tsui and Treagust's case studies used a two-tier diagnostic instrument and interviews to evaluate students' understanding in terms of genetics reasoning the students had learned from *BioLogica*, and their case studies also touch on the potential of bilingual representation of biological concepts in improving learning of English language learners. Encouraging more non-English native speakers to participate at all levels in science education appears to be increasingly important in the age of globalization (cf. Fensham, 2011). Niebert, Riemeier, and Gropengießer's study used interviews to explore students' metaphorical understanding of imperceptible phenomena (e.g., cell division at the *microscopic level* and climate change at the *macroscopic level*) by means of familiar representations of phenomena in the *mesocosm* (or the world of medium dimensions within human perception). Using a microgenetic method, Srivastavas and Ramadas examine how university students learned at the *symbolic or molecular level* in visualizing the double-helix structure of DNA. Using observations, Verhoeff, Boersma, and Waarlo report their critical appraisal of secondary students' systems thinking skills in two modeling studies for learning the complex living systems (cells and ecosystems).

The Conclusion chapter presents a synthesis of the themes from the chapters 2 to 18 and their analysis based on the examination of these chapters using the proposed theoretical cube model as a lens. Useful chapter examples are cited to illustrate the common themes and the ways multiple external representations (MERs) and their pedagogical functions can contribute to improving biological education across different content areas and contexts and to meet the challenges in the twenty-first century.

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research projects on multiple representations in teaching and learning of biology can benefit biological education researchers and inform biology teachers and biology teacher educators in improving their classroom practice in one way or another.

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