GUEST EDITORIAL

The Landscape of Nanotechnology Education

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THE LANDSCAPE OF NANOtechnology education is expansive. The many features that compose it challenge our abilities as educators to convey related knowledge to future generations of scientists and engineers. The basic sciences underlying the field are well established, but the methods used for teaching the engineering and technology associated with nanoscale systems continue to evolve. The fundamental aspects of nanoscience are the subjects of chemistry and physics, but nanoengineering finds itself taught across the disciplinary spectrum of engineering programs. In the end, each discipline has something different to say about our nanoworld. Beyond engineering, the entire nanotechnology enterprise relies on our ability to operate machinery of ever-increasing sophistication that is used to design, manufacture, and integrate nanoscale devices into systems that improve our everyday lives. This special issue of *IEEE Nanotechnology Magazine* highlights various aspects of nanotechnology education ranging from the governmental policies that are in place to define and support educational programs to advances in educational techniques that allow students to grasp the nanoscale world.

The three articles in this issue address different features of contemporary nanotechnology education. Dr. Lisa E. Friedersdorf, director of the United States National Nanotechnology Coordination Office, opens with an overview of federal programs in the United States that have been developed under the National Nanotechnology Initiative. In "Developing the Workforce of the Future," she discusses the programs that have addressed research capacity, education, and workforce development in the United States. Many government agencies have programs focused on some aspect of nanotechnology education that, when taken together, serve millions of students and teachers as well as members of the general public. The range of activities associated with these efforts is truly amazing and underscores the need for coordination at the national level. The high-level framework described in this article has elements that are likely recognizable to educators around the world, including programs designed for K–12 and undergraduate students.

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In the second article, "Practical Works on Nanotechnology," Prof. Reasmey P. Tan et al. at the University of Toulouse details educational programs that have been used at their university to teach elements of nanotechnology to a range of students. Focusing course modules on microelectronics, the team provides undergraduates with hands-on training using processing techniques for manufacturing devices. This training includes the use of clean room facilities along with all the associated equipment for micro/nanofabrication. Students create devices with specific functionality (sensing or energy storage) and test their performance. The authors share practical concerns related to teaching this type of course. As in many other universities, outreach to younger learners is part of the overall educational program at Toulouse. Also described are the activities the authors have used to capture the imaginations of middle school students, including projects that are easily completed in the middle school classroom.

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Finally, in "Virtual Reality to Improve Nanotechnology Education," Prof. Reza Kamali-Sarvestani et al. describe their efforts to use virtual reality to teach elements of nanotechnology to students. Instead of actually having them build physical devices, the authors use virtual reality simulations to guide students through the process of fabrication and characterization. They have developed simulations that introduce students to the cleanroom environment, allowing them to observe the processing that occurs in these types of facilities. Virtual reality tools provide exciting opportunities for nanotechnology education because they can engage students far better than more traditional media while at the same time allowing them virtual access to equipment and facilities that might not otherwise be available. Taken together, these articles broadly reflect nanotechnology-related education around the world—from the strategic positioning of programs at the national level down to specific tools that individual instructors are using to help students understand the landscape of the nanoscale world.