Innovative Laboratory Design

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Laboratories serve a vital and varied function in undergraduate STEM education. At a minimum, they provide a physical context for the fundamental concepts and theories of science and engineering. Among their varied uses, laboratories allow students to observe behavior, measure properties, verify theories, examine and characterize specimens, learn and practice the scientific method, and explore possibilities. From a pedagogical perspective, properly designed and managed laboratories provide rich active learning experiences for students that help them develop a variety of professional and technical skills. As physical facilities, laboratories provide an excellent educational platform for discovery-based learning activities.

In the first chapter, Johnson demonstrates the value of incorporating the use of advanced instrumentation, once within the domain of researchers only, into undergraduate chemistry laboratories. Specifically, he found that the use of liquid chromatography–mass spectrometry experiences in undergraduate settings has allowed the department to abandon the typical physical, analytical, inorganic, and biochemistry laboratories in favor of a two-semester integrated laboratory. Pratap, Hunter, and West describe the use of the Internet to provide remote access to instrumentation in the fields of astronomy, chemistry, and chemical engineering. Anecdotal evidence indicates that the value of access to and use of remote instrumentation is quite good. Boothby and Kibler describe the introduction of flow cytometry, the principal means used to analyze individual cells, to undergraduate students. They cite an example of the use of flow cytometry in an inquiry-based approach to study factors affecting phagocytosis of fluorescent-labeled yeast by *Tetrahymena sp.* Galvez discusses the development and implementation of an experimental apparatus that allows undergraduate students to design and conduct experiments to verify the predictions of quantum mechanics. Once the strict purview of Einstein and his contemporaries, such experimental setups facilitate the presentation of the fundamentals of quantum mechanics to undergraduate students in an understandable fashion. Slack and Wheatly describe a project that demonstrates that, with proper care and design, physical disabilities are not barriers for student participation in laboratories and field trips.

The value and role of laboratories in undergraduate STEM education is well understood. One of the central challenges to the academy is to optimize the opportunity that laboratories provide to incorporate active and discovery-based learning pedagogies. The reliable assessment of student learning outcomes appears to be another challenge that needs to be addressed. Much so-called assessment data appear to be anecdotal and do not provide a basis for judging the effectiveness of laboratories in achieving specific learning outcomes. Finally, but certainly not the least of the challenges facing STEM education, is the need to maintain and continually update laboratory facilities and instrumentation and to ensure universal student access to the laboratories. Considering the financial constraints, more emphasis needs to be given to developing true partnerships between industry, universities, and colleges and funding agencies to continually enhance STEM laboratories.