Vision and Change in Undergraduate Biology Education: A Call to Action

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To the PKAL LSC Community: This report is the culmination of four years of reflecting on and imagining the future of undergraduate biology education that engaged a broad and diverse range of practitioners and stakeholders (http://www.visionandchange.org). It ends with a call to action to the life science community:

> *As life scientists, we stand at the forefront of a new movement to convey the excitement and potential of the fresh direction the discipline is taking, a direction that promises to improve undergraduate biology education and to ensure that all undergraduates develop the level of biological literacy they need to understand, contribute to, and make informed decisions about the complex problems facing our world.*

Their rationale for vision and change is focused on curricular and programmatic change, as well as on new approaches to faculty and institutional development. Careful study, particularly of chapters 2 & 3, suggests significant opportunities for vision and change at the level of the physical learning environment.

We invite your attention and comments to the excerpts from the most relevant chapters. Space provided for notes.

Chapter 2

Biology in the 21st century (NRC 2009) requires that undergraduates learn how to integrate concepts across levels of organization and complexity and to synthesize and analyze information that connects conceptual domains. To meet this challenge, we can no longer rely solely on trying to cover a syllabus packed with topics to be covered in lecture and guided laboratory sessions—an approach that can be counterproductive and can often leave students with a misguided and, possibly, negative impression of biology. …even though life sciences curricula typically serve biology majors, introductory courses help prepare all students to understand the natural world and many significant challenges of the 21st century. Although instructors teaching an introductory course cannot be expected to present the same material that will be developed in a full curriculum for majors, an introductory course should still use the core concepts and competencies to provide a solid foundation for all students. (See report, pages 11 ff for Core Concepts).

Core Competencies and Disciplinary Practice:

◆ Ability to apply the process of science. *Biology is evidence based and grounded in the formal practices of observation, experimentation, and hypothesis testing.* Studying biology means practicing the skills of posing problems, generating hypotheses, designing experiments, observing nature, testing hypotheses, interpreting and evaluating data, and determining how to follow up on the findings. In effect, learning science means learning to *do* science.	**Implications for Planning Learning Spaces:**

◆ Ability to use quantitative reasoning. *Biology relies on applications of quantitative analysis and mathematical reasoning.* All students should understand that biology is often analyzed through quantitative approaches. Developing the ability to apply basic quantitative skills to biological problems should be required of all undergraduates, as they will be called on throughout their lives to interpret and act on quantitative data from a variety of sources.	**Implications for Planning Learning Spaces:**

◆ Ability to use modeling and simulation. *Biology focuses on the study of complex systems.* A variety of computational educational tools is readily available to examine complexity as it arises in biological systems. These tools can simulate many interacting components and illustrate emergent properties that allow students to generate and test their own ideas about the spatiotemporal complexity in biology. Today, modeling is a standard tool for biologists, so basic skills in implementing computational algorithms for models are increasingly being incorporated into the undergraduate curriculum.	**Implications for Planning Learning Spaces:**

◆ Ability to tap into the interdisciplinary nature of science. *Biology is an interdisciplinary science.* Integration among subfields in biology, as well as integration between biology and other disciplines, has advanced our fundamental understanding of living systems and raised a number of new questions. As exciting new areas of study emerge from the interstices, solid grounding in the sciences, including computer science and social science, can advance the practice and comprehension of biology. Accordingly, all students should have experience applying concepts and subdisciplinary knowledge from within and outside of biology in order to interpret biological phenomena. …For those not majoring in biology, the inherent interdisciplinary nature of biology practice lends itself to forming connections between biology and other sciences and, in so doing, can help all students understand the way science disciplines inform and reinforce each other.	**Implications for Planning Learning Spaces:**

◆ Ability to communicate and collaborate with other disciplines. *Biology is a collaborative scientific discipline.* Biological research increasingly involves teams of scientists who contribute diverse skills to tackling large and complex biological problems; therefore, all students should have experience communicating biological concepts and interpretations. As the science of biology becomes more interdisciplinary in practice and global in scope, biologists and other scientists need to develop skills to participate in diverse working communities, as well as the ability to take full advantage of their collaborators' multiple perspectives and skills. Effective communication is a basic skill required for participating in inclusive and diverse scientific communities. Communicating scientific concepts through peer mentoring helps students solidify their comprehension and develop the ability to communicate ideas not only to other biology students, but also to students in other disciplines. Practicing the communication of science through a variety of formal and informal written, visual, and oral methods should be a standard part of undergraduate biology education.	**Implications for Planning Learning Spaces:**

◆ Ability to understand the relationship between science and society. *Biology is conducted in a societal context.* Biologists have an increasing opportunity to address critical issues affecting human society by advocating for the growing value of science in society, by educating all students about the need for biology to address pressing global problems, and by preparing the future workforce. …Cross-disciplinary opportunities for students to explore science in a social context may be generated through real-life case studies embedded in biology courses, or in social science courses designed specifically to explore the effect of science and technology on human beings.	**Implications for Planning Learning Spaces:**

Chapter 3

...the time has never been better to focus on student learning and to integrate research and education to attract more students to explore the life sciences, both for career options and to better understand the complex world in which they live.

Traditionally, introductory biology courses have been offered as three lectures a week, with, perhaps, an accompanying two- or three-hour laboratory. This approach relies on lectures and a textbook to convey knowledge to the student and then tests the student's acquisition of that knowledge with midterm and final exams. Although many traditional biology courses include laboratories to provide students with hands-on experiences, too often these "experiences" are not much more than guided exercises in which finding the right answer is stressed while providing students with explicit instructions telling them what to do and when to do it.

Action items:

- Engage students as active participants, not passive recipients, in all undergraduate biology courses.
- Use multiple modes of instruction in addition to traditional lecture.
- Ensure that undergraduate biology courses are active, outcome oriented, inquiry driven, and relevant.
- Facilitate student learning within a cooperative context.
- Introduce research experiences as an integral component of biology education for all students, regardless of their major.
- Integrate multiple forms of assessment to track student learning.
- Give students ongoing, frequent, and multiple forms of feedback on their progress.
- View the assessment of course success as similar to scientific research, centered on the students involved, and apply the assessment data to improve and enhance the learning environment.
- (See pages 25 & 27 for information on assessment and on student-centered learning resources.) ■