Learning for the Future in Bioengineering: Building Bridges between Learning Scientists and Engineering Educators

Abstract

No one discipline or intellectual community alone can address the challenges of preparing professionals for the twenty-first century, particularly in rapidly changing fields like bioengineering. This interactive symposium brings together learning scientists and engineers to discuss what we know and understand from research that bears upon the development of adaptive life-long learning in bioengineering. Collaborating with learning scientists, engineers will address questions of what should be learned and how it should be taught and assessed. Together they will address past and current research which may influence the incorporation of educational theory within bioengineering education.

Educational and Scientific Importance

The twenty-first century brings with it new demands and challenges for which professionals need to be prepared. While economists and others have attempted to predict some of the skills and knowledge that will be needed in the future (SCANS Commission, 1991; Murnane and Levy, 1996), they also recognize that society and the world of work are changing so rapidly as to require learning and adaptation in unprecedented ways.

In this regard, as a particularly rapidly developing field, biomedical engineering is a provocative case in point. Biomedical engineers need to have knowledge and skills in disciplines relevant to their field of engineering, including biology and medicine. They also need to be able to apply mathematical, scientific, and engineering principles to real world challenges; formulate and solve engineering problems; and communicate fluently in writing and speaking. Because bioengineers participate in multiple disciplinary communities and must collaborate with other types of engineers in the workplace, they must also be able to function effectively in collaborative teams. But above all, they must be life-long learners. They must be able to continue to learn the new knowledge and skills emerging in their relevant disciplines as well as be able to adapt to the uncertainties of future problem situations they will encounter. In addition, they must be able to master with fluency emerging information and communication technologies.

What do such goals imply for programs in undergraduate bioengineering? In light of such an uncertain future, how does one determine what bioengineering students should learn, how they should be taught, and how bioengineering learners should be assessed?

In education, it is becoming increasingly clear that no one discipline or intellectual community alone can address such challenges as these. To address and meet such challenging goals will require bringing together multiple perspectives, knowledge and understandings from various communities—in this particular case, communities of experts in the various disciplines of bioengineering as well as experts in the sciences of learning.

For example, from their studies of experts and expertise, learning scientists have found that experts' strategies for thinking and problem solving are closely linked to rich, well-organized bodies of knowledge about subject matter (deGroot,1965; Chase and Simon, 1973). Experts' knowledge is connected and organized around important concepts (e.g., Newton's second law of motion); it is "conditionalized" to specify the contexts in which it is applicable; it supports understanding and transfer rather than only the ability to remember facts and formulas. Novices' initial interpretations of problem situations tend to focus on surface features of problems rather than on important conceptual ideas; novices often "search for formulas" rather than initially approaching problems from a qualitative standpoint (Chi, Feltovich & Glaser 1981). These initial interpretations (representations) have an important impact on the subsequent direction of the problem solving process. The ability to fluently recognize and interpret meaningful patterns of information is an extremely important characteristic of expertise (Bransford, Vye, Frank, and Sherwood, 1989).

Learning scientists have also found that people can reach a level of skilled expertise in a discipline without becoming adaptive experts (Hatano and Inagaki, 1986). Adaptive experts have acquired a combination of flexible knowledge, skills, beliefs about themselves as learners, and attitudes toward new learning that set the stage for lifelong learning (Bransford and Schwartz, in press; Wineburg, in press). An emphasis on adaptive expertise brings with it new methods for assessing the quality of learning and transfer.

In a recent report of the National Academy of Science, learning scientists have summarized what they know and understand about "how people learn," and educators in the fields of mathematics, science and history are now attempting to apply this knowledge and understanding to K–12 education in these fields (Bransford, Cocking, and Brown, 1999; Donovan, Pellegrino & Bransford, 1999).

Bioengineering represents a whole new domain of knowledge and expertise as yet unaddressed by learning scientists. Thus, bioengineering education represents an opportune site for collaboration and the building of intellectual bridges between learning scientists and engineers. In this symposium we propose to do just that.

The purpose of this symposium is to bring together learning scientists and engineers to consider what we know and understand from research that bears upon the development of adaptive learning in bioengineering across the life-span. Such knowledge might then be used by educators and others to better prepare bioengineering learners for the challenges and opportunities they will face in their lifetimes.

Objectives of this Interactive Symposium

This symposium will bring scholars from the learning sciences together with engineers to address the following issues…

> What should be taught in undergraduate bioengineering education?
>
> How should it be taught?
>
> How should learning in bioengineering be assessed?
>
> What is the research base for answering the preceding questions, and how do we build a community of learners to address these questions?

Learning scientists will bring to bear what they know about how people learn to address these questions. In turn, bioengineers-- through their work with learning scientists in designing new curricula and technologies for bioengineering education-- will add to the field's knowledge of how people learn.

The format of the session will involve each presenter giving a 10-minute presentation in which he or she will speak from her/his own research and work in curricular design to respond to these common questions. Presentations will be followed by a ten minutes of remarks by each of the discussants. The discussants are each heads of NSF-funded projects which have been established to incorporate interdisciplinary input (one in biology, one in learning science) towards improving bioengineering education. The remainder of the 90-minute session will consist of interactive discussion among the presenters, discussants, and the audience around areas of agreement and disagreement. The discussion will be moderated by the chairperson. A brief summary of each presentation is provided below.

Teaching a Biological Perspective to Engineers

Cynthia J. Atman and Jennifer Turns, University of Washington

Productive interactions among disciplines including the learning sciences, domain experts, and education researchers have led to significant advances in understanding about education in the sciences (e.g., physics) and mathematics (e.g., statistics). The importance of having a deep understanding of students' development of concepts as they are learning about a domain has been underscored by this research. This entails an understanding of student alternate frameworks at both the individual concept and the larger system level, as well as an understanding of related conceptual change processes. We are developing a research-based understanding of engineering student alternate frameworks of biological concepts. We are using this understanding to design instruction that helps engineering students develop a biological perspective of engineering.

Biology represents the newest fundamental science for engineers. All engineering students need a biological perspective to fully understand the impact of engineering solutions. In our case, taking a research-based approach to curriculum design requires more than an understanding of alternate frameworks and conceptual change in biological concepts. In addition, we need to clarify what it means for engineering students to have a biological perspective of complex engineered systems. In our talk we will describe the scope of our instructional development effort. We will focus specifically on the development of a junior level project-activity that is being designed to help students understand issues of biocomplexity.

"How People Learn": Building a Community of Learners in Bioengineering

Sean P. Brophy, John D. Bransford, and Robert J. Roselli, Vanderbilt University

This presentation will discuss the results from a collaboration that combined the expertise of engineers and learning scientists to improve engineering education. Engineering professors have long known that solving problems is a necessity of good instruction for their students. One of their fundamental goals is to develop students with good problem solving skills. However, sustained inquiry into meaningful challenges has not always been the norm. Example problems solved by the professor during class time are often designed to highlight a single key concept and links between key concepts are delayed until the students have mastered these key basics first.

Through the collaborative project that we shall describe, engineers have learned important principles of effective learning environments and learning scientists have learned more about the complexity of bio-engineering domains and how to represent them. This presentation will discuss how the different groups have learned from one another and the initial effects on student learning that have resulted from the collaboration.

An example of the collaboration involves work with new theories of learning such as those presented in "How People Learn" (Bransford, Brown & Cocking, 1999). This report articulates a framework for designing and evaluating effective learning environments. The learning scientists have been working with engineers to explore how to instantiate these principles into undergraduate bioengineering courses. Through this collaboration several engineers realized the linear progression through discrete domain concepts does not always provide an optimal method for organizing instruction. For example, in the Spring 2000 term, several learning scientist observed an introductory course in biomechanics to identify difficult concepts for students to learn and identify consistent features of the professor's instructional practice. Through group discussion the research team discussed various alternatives for employing the principles of the HPL framework and the content of the domain. As a result the professor is reorganizing his course in a way that reduces the amount of lecture time, increase the amount of in class interaction time, and incorporates new methods for assessing students’ progress during a specific unit of instruction (formative assessments). Examples of these changes will be presented and discussed.

Developing Challenging Curricula for Bioengineering: The Case for Collaborative Design

David E. Kanter, John B. Troy, and Brian J. Reiser, Northwestern University

This presentation will overview lessons learned from a novel curriculum development effort. A collaboration between Biomedical Engineering (BME) and Learning Sciences (LS) researchers is actively developing modular materials for instruction in BME, currently in the subject area of Systems Physiology. It is with such uniquely and collaboratively designed instructional materials that we intend to develop Biomedical Engineers who have, beyond expertise in engineering, expertise in adaptation. Although both BME and LS recognize the need (as does the Accreditation Board for Engineering and Technology) to train professionals with a capacity for lifelong learning requisite to contributing to a rapidly evolving field, BME and LS are finding that there is much to learn from one another on the way to meeting this challenge.

The researchers will comment on lessons learned from the BME and LS perspectives respectively, during the initial stages of this collaboration. Briefly, LS suggested that learning goals (conceptual understanding, cognitive skills, procedural skills, and attitudes) be explicitly articulated as the target of the module design effort; this articulation was difficult for BME. Subsequently, LS found it demanding to define strategies by which to assess improvement in the understanding, skills, and attitudes that had been targeted. LS also recommended that the learning goals, once defined, be addressed in an inquiry-driven manner by having students explain a conundrum or tackle a problem. BME found it easier said than done to define challenges of this sort, and LS found its insufficient mastery of the content knowledge a hindrance to devising such challenges itself. Nevertheless, certain successes along all fronts and progress toward the design of the Systems Physiology module will be shared during this presentation.

Adaptive Learners and Learning in Bioengineering

Frank Fisher and Penelope Peterson, Northwestern University

In the cognitive science literature, experts are characterized as being able to think clearly and effectively in a particular subject area, having an extensive amount of content knowledge which is organized such that it reflects a deep understanding of the subject material. The *adaptive expert* is an extension of this concept, referring to an individual who possesses the attributes of an expert, while also displaying additional “adaptive” qualities that enhance and augment his or her ability to first learn and subsequently apply their content knowledge. Using the existing cognitive science literature, a framework describing an adaptive expert has been developed and is based on four dimensions: multiple perspectives, metacognition, goals and beliefs, and epistemology. A Likert-scale survey based on the adaptive expertise framework has been developed and administered to Biomedical Engineering senior undergraduates (n=44) and freshmen engineering students (n=202) at Northwestern. Individual students who scored as either highly adaptive or highly non-adaptive were subsequently interviewed to gather additional data on their undergraduate experience. Results indicate an increase across each of the four dimensions of the adaptive expertise framework between students in their freshmen and senior year. In addition, preliminary work shows that there may be a relationship between adaptiveness and GPA for undergraduate engineering students.

We will present the results of this work, with a focus on how attention to this model suggests changes to bioengineering education. Specifically, as the amount of content knowledge of potential relevance to a bioengineer continues to increase and diversify, schools will be unable to cover both the breadth and depth of content information required. However, it is our contention that a bioengineering curriculum that actively seeks to foster the development of adaptive expertise in its students will be able to better prepare their students for later learning challenges. This is directly related to ABET's curricular objective of "preparing graduates to pursue a productive engineering career that is characterized by continued professional growth."

References

Bransford, J.D, Brown, A.L, & Cocking R R. (Eds.) 1999. How people learn: Brain, mind, experience and school. Washington, DC: National Academy Press.

Bransford, J. D., & Schwartz, D. (in press). Rethinking transfer: A simple proposal with multiple implications. In A. Iran-Nejad & P. D. Pearson (Eds.), Review of Research in Education (Vol. 24). Washington, DC: American Educational Research Association.

Bransford, J. D., Franks, J. J., Vye, N. J., & Sherwood, R. D. (1989). New approaches to instruction: Because wisdom can't be told. In S. Vosniadou & A. Ortony (Eds.), Similarity and analogical reasoning (pp. 470-497). New York, NY: Cambridge University Press.

Chase, W. G., & Simon, H. A. (1973). Perception in chess. Cognitive Psychology, 1, 33-81

Chi, M. T. H., Feltovich, P. & Glaser, R. (1981). Categorization and representation of physics problems by experts and novices. Cognitive Science, 5, 121-152.

deGroot, A. (1965). Thought and choice in chess. The Hague: Mouton

Donovan, M. S., Bransford, J. D., & Pellegrino, J. W. (Eds.) 1999. How people learn: Bridging research and practice. Washington, DC: National Academy Press.

Hatano, G. & Inagaki, K. (1986). Two courses of expertise. In H. Stevenson, H. Azuma, & K. Hakuta (Eds.), Child development and education in Japan. New York: W. H. Freeman.

Murnane, R. J. & Levy, F. (1996). Teaching the new basic skills. New York: Free Press.

SCANS Commission (1991). What work requires of schools: A SCANS Report for America 2000. Washington, D.C: The Secretary's Commission on Achieving Necessary Skills, U.S. Department of Labor.

Wineburg, S. (in press). Reading Abraham Lincoln: An expert/expert study in the interpretation of historical texts. _Cognitive Science_.