

Educational Initiatives for a Biobased Economy

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Subgroup Chair: Mark Worden, Michigan State University, worden@egr.msu.edu

Introduction

Many recent federal, industrial, and academic studies have concluded that the U.S. economy of the 21st century will be biobased (Armstrong, 1999; National Research Council, 2000). During the transition from a petroleum-based economy to a biobased economy, products and processes based on biological raw materials will replace those based on fossil fuels. Biorefineries will use many types of biomass sources and produce a broad range of carbon-based products, including energy fuels, chemicals, oils, biomaterials and many types of materials.

Many technological challenges must be overcome for this vision of a biobased economy to be realized. Key “barrier topics,” identified in the *Technology Roadmap for Plant/Crop-Based Renewable Resources 2020* document, fall into four categories: (1) plant science, (2) plant/crop production, (3) processing, and (4) utilization. In many instances, these barrier topics represent complex problems that cut across multiple science and engineering disciplines. To address these problems, skilled scientists and engineers will be required to work in cross-functional teams. A recent National Research Council study concluded that process engineers need to be better trained in the biological sciences, and that biologists need to be trained in process engineering, so that the biologists and engineers could work together effectively to establish the technical infrastructure for developing, manufacturing, and using biobased products (National Research Council, 1999).

The educational infrastructure needed to provide such training is currently available in conventional academic programs, which provide a narrow focus and do not encourage interactions between students from different departments. Innovative, new training programs are needed that minimize barriers and provide a more integrated approach. These programs must train students to communicate effectively, to solve problems, and to design processes in a multidisciplinary setting.

Proposed Educational Models

Four educational models are proposed below to help meet the training needs of a biobased economy. These models capitalize on the traditional strength of universities in developing effective educational programs and also integrate industrial expertise to ensure relevance. Emphasis is placed on developing educational materials in a format suitable for distance education (e.g., internet course offerings). In this way, the educational opportunities can be made available to a broad audience, thus maximizing their value.

Model 1: Development of multidisciplinary doctoral training programs. Such programs would produce Ph.D.s able to integrate knowledge from a wide range of disciplines, solve complex problems inherent to the biobased industry, and train future employees of the biobased industry. Suitable programs should feature significant coursework requirements from outside the home department. Research projects should involve multidisciplinary collaboration and address

research priorities identified by the National Research Council. Priority areas for biology include genetics, physiology, and biochemistry of plants and microbes; protein engineering; and maximization of biomass productivity. Priority areas for engineering include methods to store and process biomass, improved methods to convert biobased materials into higher value products, and downstream processes for product separation and purification.

Involvement of industry of the biobased industry with the training programs is necessary to maximize relevance of the programs and to aid in student recruitment. Industrial partners can also add value to the training program by providing internships and serving on industrial advisory boards and Ph.D. committees.

Model 2: Development of courses having special relevance to the biobased industry. Research sponsored by this regional project will yield important new knowledge that should be quickly and widely disseminated by incorporation into courses. Such courses should focus on topics relevant to utilization of diverse biological materials, improving technologies for processing and production of sustainable energy or other valuable functional molecules, and management of wastes associated with biobased product formation. Examples of relevant technical course topics include

- overview of engineering principles for scientists
- overview of biotechnology principles for engineers
- modeling of biological systems
- bioprocessing and bioseparations
- sensors, monitoring and automation for bioprocesses
- advanced research techniques of relevance to biobased processes

In addition to technical courses, there is also a need for courses on professional skills that are especially relevant to biobased industry. For instance, conventional curricula do not teach students to work effectively in multidisciplinary teams on problems related to bioprocessing. In addition, few faculty and graduate students are trained in methods to develop virtual courses.

Model 3: Research opportunities for undergraduates. Future employees of the biobased industry at the B.S. level will also need to possess a broad range of knowledge and have hands-on experience with bioprocess technologies. Traditional undergraduate curricula generally do not provide such knowledge and experience. Thus, the regional project should promote recruitment of talented students into faculty labs to obtain research experience. Development of novel courses that provide laboratory experience in research techniques relevant to bioprocessing should also be encouraged. Research opportunities for undergraduates would have a secondary benefit of encouraging outstanding undergraduates to consider graduate training.

Model 4: Educational outreach to K-12. Educational outreach programs on science and engineering topics should be developed for K-12. These programs would offer several benefits, including stimulating interest in science and engineering among pre-college students, informing the public about the potential benefits of biobased products, and enhancing public sentiment of agricultural biotechnology. As an example of such programs, workshops could be held in which science teachers are shown how to conduct demonstrations related to bioprocessing, process monitoring, microbial ecology, etc. These experiments would be linked to instruction

concerning the important geochemical cycles in nature. Teachers (and outstanding high school juniors and seniors) could also be recruited to work in university labs over the summer.

Course delivery platforms

Virtual courses. Because the participants in this regional effort are geographically dispersed, a distance-learning platform for courses developed as part of this project is strongly recommended. Internet-compatible courses can serve students in virtually any location. Moreover, virtual courses can be easily co-developed and co-taught by faculty located at different universities. In contrast, conventional lecture courses can only serve a limited audience, and co-teaching by faculty at different universities is inconvenient, if not impossible.

Current technology allows internet courses with a broad range of multimedia features to be delivered as streaming multimedia movies. For example, an instructor can outline a lesson with presentation software, and then scroll through the outline while explaining the material using a headset microphone and annotating it with a writing tablet, mouse and keyboard. Multiple, synchronized windows can be used, so that several types of instructional materials can be used simultaneously, including a movie of the instructor explaining the material, scanned photographs, spreadsheets, computer graphics, and animations. The developed course materials can be also available to the users in asynchronous mode. Thus, these courses can also be used for professional development and training of faculty and staff interested to enhance their skills in these areas. It is anticipated that other distance education media such as satellite communication method could also be used to offer these course. Advanced pedagogical features, such as interspersing short presentations with questions that require student responses, are readily implemented. The powerful multimedia capabilities of internet courses allow them to rival or even surpass conventional chalkboard lectures in effectiveness.

Conventional courses. In instances where Internet delivery is impractical (e.g., lab-based courses), conventional, on-site course delivery may be the best model. However, the technical content of such courses should be disseminated via publications in pedagogical journals.

Organizational Structures

The educational models described above are broad in scope and would involve faculty from a variety of departments over a wide geographical area. Several of the activities require collaboration among faculty (e.g., development of new courses), sharing of information (e.g., dissemination of information on effectiveness of new training programs) and selection of technology platforms (e.g., software to use for internet course development).

Education Committee. A Regional Education Committee would coordinate development of the educational programs. Key activities of this committee are summarized below:

- interface with other organizations involved in education (ASEE, USDA, DOE)
- identify educational needs of the biobased industry
- encourage faculty to develop educational materials in strategically important areas
- help disseminate educational materials
- organize short courses and conferences related to educational activities
- assist with assessment of educational programs
- encourage pedagogical research on effectiveness of novel educational programs
- recommend curricular revisions that would promote a biobased economy
- assist faculty with course development, advertisement, and distance delivery

Training Programs and Centers. Center-level educational programs should be developed to assemble the critical masses of faculty, educational resources, and activities necessary for comprehensive educational programs. Because of the connection between research and education, center-level educational activities are expected to be tightly integrated with center-level research programs. The principal educational challenge is to develop a curriculum that will satisfy the needs of all stakeholders and be adopted by all academic institutions involved. Lead institutions who have developed model centers should be identified and consulted by schools intending to establish a center. Expected activities of these centers are summarized below:

- develop multidisciplinary graduate training programs
- hold conferences/short courses
- foster the integration of science and engineering (e.g., establish a clearinghouse to help match researchers having complementary expertise)

Performance assessment parameters and quality improvement parameters will include grades, number and quality of students enrolled, number and quality of participating faculty, curriculum, relevance of research projects, national recognition of program, evaluation of student performance over project duration, number of new courses developed, satisfaction of graduates as measured by survey, and evaluation of faculty teaching performance over project duration.

Industrial advisory committee. Industrial advisory committees are required to advise on industrial needs of the program. The industrial advisory committee would contribute in several ways, including those listed below:

- advise faculty on the industrial relevance of educational programs
- assist in assessment of educational programs and the quality of graduates
- provide internship opportunities for students and sabbatical opportunities for faculty
- assist in placement of trainees (e.g., job-placement activities at conferences)

Course coordinators. Development of new courses will leverage faculty expertise in teaching and research related to biobased products. A course coordinator will be designated for each new course. The responsibilities of the course coordinator are summarized below.

- coordinate course development with collaborators
- communicate with industry to ensure relevance of course content
- work with Regional Education Committee to offer the course to a broad audience
- conduct course assessment and improvement activities

References

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