EDUCATING BIOTECHNICIANS

FOR FUTURE INDUSTRY NEEDS

A report from a conference sponsored by the National Science Foundation and the American Association of Community Colleges

APRIL 28–30, 2008 | SCOTTSDALE, AZ

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This publication is based upon work supported by the National Science Foundation under grant number 0402310 to the American Association of Community Colleges. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author and the individuals quoted and do not necessarily reflect the views of the National Science Foundation.

The American Association of Community Colleges (AACC) is the primary advocacy organization for the nation's community colleges. The association represents 1,200 two-year, associate degree–granting institutions and more than 12 million students. AACC promotes community colleges through five strategic action areas: recognition and advocacy for community colleges; student access, learning, and success; community college leadership; economic and workforce development; and global and intercultural education.

The National Science Foundation (NSF) is an independent agency of the U.S. Government whose mission is to promote the progress of science; to advance the national health, prosperity, and welfare; and to secure the national defense. The foundation competitively awards grants for research and education in the science, technology, engineering, and mathematics fields.

Text by: Madeline Patton
Editor: Ellen Hause
Design: Larnish & Associates, Inc.

The editor acknowledges with gratitude the contributions of the conference steering committee, the conference participants, and the NSF program officers. Special thanks to Duncan McBride, V. Celeste Carter, Lynn Barnett, and Linda Inabinet for their assistance.

 This report is also available online at www.aacc.nche.edu/ateprogram under publications.

Printed in the United States of America.

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Executive Summary

How to strengthen technician education to meet the needs of the biotechnology industry was the question before the 50 people who participated in the *Educating Biotechnicians for Future Industry Needs* conference from April 28 to 30 in Scottsdale, Ariz. The participants were from higher education, secondary schools, industry, government, and professional organizations.

The conference specifically addressed industry needs for the next five years within the areas of health, medical, agriculture, industrial and environmental biotechnology, and emerging areas such as biotechnology with microelectromechanical systems (BioMEMS) and nanotechnology (BioNanotechnology), and personalized medicine. Industry participants delineated employers' expectations for technicians. Small and large group discussions focused on how community colleges can educate traditional college-age students, who must acquire a solid basic knowledge for entry-level biotech posts, and also postbaccalaureate students, who may have advanced degrees in science but lack the laboratory skills needed to gain employment in the biotech industry.

Consensus was reached on recommendations, which appear on the next page. The recommendations are aimed at high school, two-year and four-year college programs, government agencies, and the biotechnology industry. Some of the recommendations will require relatively minor revisions to existing biotechnology education programs while others will involve additional resources. Some may require initial external funding. Conference participants also initiated small working groups to plan next steps and to involve other individuals from the biotechnology community who might aid in accomplishing the recommendations.

The National Science Foundation (NSF) sponsored the conference through a grant to the American Association of Community Colleges, which represents more than 1,200 associate degree–granting institutions that enroll more than 12 million students—almost half of all U.S. undergraduates. The NSF regularly brings together scientists, educators, and other stakeholders to share their opinions on critical issues such as biotechnology workforce development. The NSF currently provides $16.3 million in support of biotechnology programs through its Advanced Technological Education (ATE) program. These initiatives include the ATE Resource Center in Biotechnology (Bio-Link) at the City College of San Francisco; and the Northeast Biomanufacturing Center and Collaborative (NBC^2) at Great Bay Community College. The U.S. Department of Labor (DOL) also supports biotechnology workforce development through 25 awards in the President's High Growth Job Training Initiative and Community-Based Job Training Grants and 17 WIRED regions that have a focus on bioscience and biotechnology.

In addition to the recommendations, the report summarizes key points from five panel discussions: health and medical, industrial and environmental, food and agriculture, education, and emerging issues. Panelists shared their opinions about how the biotechnology industry will grow during the next five years, the skills that technicians will require to meet workforce needs, and their experiences with promising educational practices. The small and large group discussions that followed each panel presentation led to the recommendations.

The report is intended to guide community colleges and other educational institutions as they align their biotechnician education programs with anticipated workforce needs during the next five years, to inform funding organizations' efforts to support biotechnician education, to encourage stakeholders' involvement in biotechnician education programs, and to prompt individuals and organizations to carry out the recommendations developed during the conference.

Recommendations

Many of the conference recommendations are directed at community colleges, but the recommendations also affect other colleges, universities, secondary schools, government agencies, and the biotechnology industry. The recommendations are grounded in the understanding that biotechnology educational programs should develop exemplary technical skills in students and give students a thorough working knowledge of biotechnology applications. To address these priorities, the conference participants recommend the following:

Biotechnology curriculum should include (1) instruction in written and verbal communication, and "soft skills" such as team work and time management; (2) core curriculum courses that transfer and articulate from high school to two-year and four-year degree programs; (3) a strong theoretical understanding of the entire manufacturing process encompassing upstream and downstream processes; (4) the introduction of emerging technologies in basic biotechnology courses; and (5) the redesign of standard microbiology and biology curricula to include applications in industrial and environmental biotechnology.

Biotechnology programs should provide (1) biotechnology industry externships for community college faculty, secondary school teachers, and guidance counselors to expand their industry experience; (2) faculty teams to bring prepackaged resources and professional expertise to colleges starting biotechnology programs; (3) multidisciplinary programs for cross-training of college faculty and students (e.g., microelectronics as it relates to emerging diagnostic technologies, and materials science as it relates to emerging biofuels); and (4) a parallel analysis of skills from different subfields to support and inform retooling and retraining programs to enable biotechnicians to shift fields within the rapidly emerging industry.

Educational institutions should develop (1) clear, articulated career pathways from middle school and high school to community college and four-year biotechnology programs; (2) a process to reach agreement on standards for accreditation of biotech programs and certification of academic credentials for biotechnicians; and (3) community college food and agriculture programs that incorporate biotechnology in multidisciplinary approaches to technician education as articulated by community college leaders in a future meeting to be convened by NSF.

Relationships and partnerships should be encouraged (1) between educational institutions, industry, and state and federal agencies; and (2) in regional biotechnology efforts that prepare individuals with crossover skills that are used by particular industries located in multiple states.

Marketing and communications efforts should raise employer awareness of existing biotechnology education programs and improve public understanding of biotechnology by (1) focusing on successful biotechnicians and the programs that educated them; (2) identifying national models of educational partnerships with industry and creating case studies to publicize these successful models; (3) engaging students in cross-disciplinary approaches that bring biotechnology professionals to campuses for career seminars and classroom lessons in an array of science technology, engineering, and mathematics courses; and (4) creating innovative recruitment strategies that encourage people to enroll in biotechnology programs.

Panel Discussions

Health and Medical

In addition to good laboratory practices (GLP), biotechnology technicians employed by health and medical industries and academic institutions need a context-based understanding of biotechnology. There are multiple dimensions to this context-based understanding because in the future, technicians will be expected to participate in all levels of biotechnology, including measurement, information systems, and development of clinical applications. Biotechnicians' context-based understanding, therefore, should include a grasp of the major factors affecting the medical or health field in which they work, knowledge of how to make products or to carry out test processes in compliance with strict government guidelines, and fluency with the bioinformatics techniques needed to use biological information from digital resources.

Mark Van Dyke, assistant professor at Wake Forest University School of Medicine, anticipates that the U.S. biotechnology industry will expand in the areas of biomarkers, personalized medicine, and epigenetics (i.e., modifications that change gene expression without affecting the gene's DNA). He noted that despite the growth of clinical trials that use research in stem cells, biologic molecules, gene therapy, and regenerative medicine, few reach the randomized-control phase at multiple sites (Phase III) or postmarketing surveillance (Phase IV). As more academic laboratories and small companies do discovery research (rather than basic research), he predicts there will be greater demand for technicians with the skills and knowledge to move between academic and industry settings. Given these trends, technicians with interdisciplinary education and work experiences will be in demand.

Systems biology, cell therapies, nano-scale materials science, new drug delivery mechanisms, small molecule development, and contract research organizations are among the key factors that will affect the U.S. healthcare industry, according to Peter Johnson, president

> Biotechnology can break the code of disease and treat it. Biotechnology can produce plants resistant to pests, disease, and drought. Biotechnology can produce new fuels from cellulose and biodegradable products. There's no limit to our challenges. There's no limit to what we have to learn. And there is no limit to our ability to use this knowledge to good purpose. So you are wise, all of you, to fund and to lead the education our young people will need to join this astonishing journey.
>
> James C. Greenwood, *President and Chief Executive Officer*
> Biotechnology Industry Organization (BIO)

Biotech Industry Hungers for Skilled Workers

The biotech industry is hungry for skilled workers, but there are concerns that difficulties in finding such workers could impede the industry's growth in the United States. "Can you imagine a future with potential high-paying U.S. jobs [being] outsourced not because you can produce less expensively overseas, but because you can only produce overseas? That would be sad indeed," James C. Greenwood, president and chief executive officer of the Biotechnology Industry Organization (BIO), said during his keynote speech at the *Educating Biotechnicians for Future Industry Needs* conference.

Greenwood advises communities interested in attracting biotechnology companies to begin teaching biotechnology in elementary, middle, and high schools to encourage student interest in biotechnology careers. "To build a biotech product pipeline we are going to need a well-educated workforce pipeline. In any field the fundamentals are always important. They serve as the foundation for developing more specialized skills," he said.

He applauded community colleges for providing "the gateway for many career paths in our industry," and encouraged them to continue focusing on basic biotechnology skills. "Our companies need workers with knowledge of molecular biology, biochemistry, and cell culture. They need workers who can perform basic research, operate standard lab equipment, understand instrumentation, and follow established lab protocols. Specific procedures for advanced skills can be taught by companies' in-house education programs, but only if workers have the basic foundations in practical laboratory procedures. We need workers with excellent team work, record-keeping, and communications skills."

Greenwood noted that technicians who possess these technical skills and soft skills are able to pursue careers "not just in basic research, but jobs in drug discovery, translational research, clinical research, and FDA compliance. Lab skills and experience are also part of a good background for careers outside the labs such as biotech marketing, licensing, technical services, and managing intellectual property."

and chief executive officer of Scintellix, LLC. Already, bioinformatics skills are important as people are "scrambling to understand the biology information in digital data," and deciphering the aggregation of information that is systems biology. "By understanding the system, we can understand how to take care of patients much better," he said.

Gary Skuse, director of bioinformatics at the Rochester Institute of Technology, said bioinformatics education may not lead to bioinformatics degrees. However, students whose biotechnology courses include computer science and statistics will have a competitive advantage in the job market. He expects that the volume and rate of biological data that are

part of “high throughput science” will require more people in the future to generate, organize, analyze, and curate this information. Raymond Mariella Jr., senior scientist for biosecurity at Lawrence Livermore National Laboratory, added that it is important for technicians to understand what is involved in the data collection. In the long run, it will be important to the nation “to do at least some of the work” domestically.

To prepare technicians for these various expectations, Linnea Fletcher, chairman of the Biotechnology Department at Austin Community College (Texas), urges faculty to use their knowledge of worldwide biotech trends to develop courses and programs to fit regional employers’ responses to international happenings. This, of course, requires faculty members to have good contacts with industry personnel so they know what is going on. She attributes Austin Community College’s high job placement rate of biotech students from internships and apprenticeships to the match between its biotechnology curriculum and regional employers’ equipment, protocols, and practices, including the essential soft skills.

Industrial and Environmental

Adding more applications to the general biology and microbiology courses that aspiring biotechnology technicians take will help prepare them for the anticipated growth in industrial and environmental biotechnology. Knowing which applications to add to the curriculum and acquiring equipment for student laboratories will require more robust collaborations between educators and employers. By using these needs to instigate partnerships with industry, educators have the potential to improve both the education of biotechnology technicians and the products of the companies that eventually employ their students.

John Sterling, editor-in-chief of *Genetic Engineering and Biotechnology News*, reported that industrial biotechnology is expected to grow from a $121 billion market in 2008 to a $195 billion market in 2010. He anticipates that as molecular diagnostics tie in with personalized medicines, biotechnology’s focus will shift from disease treatment to prevention and push growth in industrial biotechnology. New interest in biofuels and plant extracts means that many technologies currently used in the biomedical fields will transfer to biomanufacturing.

Sandi Woods, operations manager of Genencor, began her career as a technician. Now her management responsibilities include hiring technicians for the company that produces industrial enzymes. When considering applicants, she looks for people who have troubleshooting skills and who have hands-on expertise with equipment. Technicians distinguish themselves when they are capable not only of monitoring a fermentation run, but also of seeing trends in processes and reporting them accurately.

Miguel Olaizola, director of production for Sapphire Energy, agrees that biotech students need experience handling large pieces of equipment. He suggests students get this experience either as part of their classroom lessons or with internships or other structured placements within industry. He would also

Soft Skills Second Only to Good Laboratory Practices Among the Qualities Biotech Employers Seek in Technicians

In addition to checking applicants' technical skills, the biotech employers at the conference said they look for technicians who communicate clearly, think critically, work well on teams, and possess other soft skills.

Applicants with firsthand experience operating industry equipment are also preferred, they said. "Having that hands-on experience, from my perspective, is key," said Sandi Woods, Genecor operations manager. She and other conference participants encouraged colleges to develop internships with industry to help students obtain critical, real-work experience.

Besides a strong background in basic biology and genetics, the recommended technical skills for biotechnicians varied according to which aspect of biotechnology the employer engages. For instance, agriculture companies look for people who know entomology, whereas medical companies seek people who have taken the computer science and statistics courses that help when performing bioinformatics tasks.

The attributes that conference participants mentioned most often as skills that biotechnicians will need in the future are quite similar to the competencies and foundation skills detailed in *Learning a Living: A Blueprint for High Performance*, the 1992 report by the Secretary's Commission on Achieving Necessary Skills (SCANS). Many of the nontechnical skills identified in the SCANS report have come to be called soft skills.

Basic SCANS skills like reading, writing, and listening matter to biotech employers who need technicians to follow directions, keep accurate records, and report results that other employees can readily understand. Whether technicians can think critically and learn continuously is particularly important to biotech employers because the industry is changing so quickly. Technicians who troubleshoot effectively, know how equipment is used, and understand upstream and downstream processes quickly distinguish themselves, according to the biotech employers.

Being congenial, timely, adaptable, and resourceful are qualities that the biotech employers identified as expectations for all employees.

like biotechnology technician education to include some lessons about the expectations for employees of start-up companies and the challenges that accompany successful innovations and growth.

For instance, Sapphire Energy's 22 employees produce fuel from micro algae. Trying to create biotechnology breakthrough products like green crude takes extremely committed individuals who are willing to work long hours, Olaizola said. If Sapphire achieves its goals, it will need 10,000 acres of algae. With the carbon biomass of one acre of algae equal to 100 acres of corn, cultivating this much algae will present an entirely different set of challenges to the company's technicians

Pin-Ching Maness, senior scientist at the National Renewable Energy Laboratory, would like young people and their parents to begin learning about biotechnology and its career opportunities in elementary and secondary schools. Offering programs that involve students of various ages in the search for useful microbes in local soils is one of the ways she suggests community colleges could stimulate interest in biotechnology.

In addition to getting more adolescents interested in biotechnology, conference participants encouraged educators and business people to recruit adults, particularly immigrants, with degrees in other fields as biotechnology

Low-Cost Model to Give Students Real Biotech Experience

Austin Community College (Texas) is working on a low-cost model to bring real-world biotechnology work experience to students on campus. "I want it to be something any community college can integrate," said Linnea Fletcher, chairman of the Biotechnology Department at Austin Community College.

Fletcher's model calls for setting aside or adding benches to campus laboratories for companies to rent. She added four benches for biotechnology incubator work in the laboratory her department shares with the Medical Laboratory Training Program. "Don't make it too expensive or too fancy. Just get it done," Fletcher said of the approach.

During a recent semester, a company that needed extra lab space used the community college benches for work on a real-time polymerase chain reaction assay. The company employee conducting the project was hired as an adjunct instructor by the college. She blended instruction about the process into an existing course and guided student interns who helped the company complete its project on time. In exchange for the laboratory space and students' assistance, the company donated a sizable quantity of consumable supplies to the community college.

technicians. The traditional progression from high school to college to work no longer applies to the many adult students who enter and exit postsecondary educational institutions multiple times even after they have earned degrees and begun careers.

Food and Agriculture

The United States' role as breadbasket of the world is widely acknowledged. Less well known is biotechnology's role in food and agriculture production, including aquaculture and forestry products. Biotechnology is expected to be a critical factor in future efforts to increase crop yields, to control diseases in animals, and to expand food production in areas where water and arable soil are in short supply. The use of technology with crops and animals is as sophisticated as it is in human health care. Whether technicians work in the field or in company laboratories that produce fertilizers, seeds, and animal vaccines, they have the added responsibility of safeguarding the food supply.

Dannette Connor-Ward, a senior scientist with Monsanto Company, encouraged educators to recruit and mentor agriculture biotechnicians in urban as well are rural areas. "There is a whole population that could do and would do [biotechnology] but they need to see somebody that looks like them," she said, referring to under-represented minority and immigrant populations. She suggests targeted marketing efforts to inform potential students that agriculture biotechnicians require less brawn and more brainpower to understand plant biology, genetics, entomology, and statistics. When students obtain data analysis skills and regulatory knowledge in college it "means people can write their ticket," she said.

Ian Watkinson, an agriculture professor at Arizona Western College explained that in areas of intense, year-round crop cultivation, technician duties range from monitoring irrigation systems to testing soils and diagnosing and remedying problems. Agriculture products are international commodities, and technicians need to understand the international nature of their work as well as regional considerations dictated by geography and weather, he said.

Katherine Krolikowski, assistant professor of biology and biotechnology at Contra Costa College (California), noted that in addition to expertise in particular skills sets, agriculture biotechnicians need to be able to learn throughout their careers and respond to changes due to weather or industry trends. She suggests that community colleges build on their tradition of preparing students to be lifelong learners by encouraging faculty and students to engage in cross-disciplinary efforts on campus and to interact with industry off campus. She urged industry to partner with community colleges. "That's a good investment for companies because community colleges are good at teaching lifelong learning," she said.

Wayne Freese, chief executive officer of Prairie Holdings Group, said the market for animal vaccines has grown with the expansion of intensive, large livestock operations. "With the concentration of livestock, diseases became huge," he said. In recent years, veterinary

Personal Encouragement Important to Inspire Women and Minorities to Science, Technology, Engineering, and Medical Careers

Effective recruiting of women and under-represented minorities for biotechnology can occur during personal conversations and with small gestures, according to Dannette Connor-Ward, a senior scientist at Monsanto. This sort of informal recruiting is something that Connor-Ward would like more female and minority college faculty members to engage in whenever possible to encourage youngsters to consider careers in biotechnology and other scientific fields.

Connor-Ward's job with Monsanto and her work as an adjunct professor at St. Louis Community College-Florissant Valley give her many public speaking opportunities. Frequently she is the only woman or only African American among a panel of speakers. Regardless of the venue or topic, Connor-Ward makes a point of mentioning how science affects people's lives in the hope that it will inspire at least one person in the audience to pursue a career in science.

After her formal presentations, Connor-Ward tries to chat or at least make eye contact with the girls and underrepresented minority students in the audience. "A lot of women need to see other women," she said. While handing out her business cards, she asks students questions about their aspirations, invites their questions about her career, and tells them to email her if they have other questions.

"They need to know that you made it, but that you had struggles just like anybody else," she said. For instance, when a teenage boy told her he did not have money for college, she explained how she used student loans to get her first degree. "I'm determined to see more women and minorities go into science. I just want that," Connor-Ward said.

> As educators we are living now in a biotech world. I believe, we must teach science and biotech. We must teach the social aspects of biotech, the economic aspects, and the political aspects. We must somehow not instill a prejudice for what the right answers may be, but rather enable all our students to come to their own decisions both individually and for the collective good, always supporting the extraordinary potential of the ordinary student.

Moira A. Gunn, *Host*
"Tech Nation" and "BioTech Nation"
Program Director for Information Systems
University of San Francisco, CA

Attentiveness to Student Needs Essential for Successful Recruiting Efforts

There is no single formula for recruiting students to biotechnology programs. Instead community colleges in various parts of the country are attracting students with programs that respond to the particular needs of students in their region.

For instance, 80% of the students enrolled in biotech programs at Austin Community College (Texas) have already earned at least bachelor's degrees, usually in a science or technology field. The postbaccalaureate students, sometimes referred to as reverse articulation students, come to the community college to learn the laboratory skills they need to gain entry with biotech employers in the metropolitan area. This phenomenon of community colleges serving bachelor's degree holders is becoming more common, particularly in biotechnology programs, across the United States.

But at Finger Lakes Community College (New York) almost all of the people in the biotech program are traditional college-age students who enroll directly from high school. They enroll at Finger Lakes because its entire associate degree biotech program articulates to the Rochester Institute of Technology (RIT). The public community college markets its biotechnology program as a significantly less expensive route to a bachelor's degree from RIT, a private college. Most of Finger Lakes' biotech students follow up on their associate degrees by transferring immediately to RIT as juniors.

Meanwhile, in the Northeast, biomanufacturing apprenticeships are encouraging nontraditional students who have no postsecondary education experience to enroll at Great Bay Community College (New Hampshire). The biotech apprenticeships include tuition scholarships and paid summer apprenticeships with industry.

Other community college educators at the conference report that they find it useful to target biotech recruitment efforts among allied health students. If students get wait-listed for nursing or other health care programs or if they find they do not like direct patient care, their prerequisite courses provide a solid foundation to pursue biotech careers. An academic background in health care is actually an asset when seeking employment with biotech companies involved in clinical trials.

medicine has become more sophisticated, allowing for real-time monitoring of diseases in herds. He anticipates that the United States will continue as the global leader in the diagnosis of diseases and toxins that affect livestock. "We are better than any other country in the world when it comes to diagnostics," he said.

He and other conference participants anticipate that veterinary medicine will become even more prominent in the future as the worldwide consumption of meat increases. They also see the need for greater coordination between federal agencies, including the sharing of information and other resources.

Education

For biotechnology technicians, community colleges provide associate degree and certificate programs, and university research facilities offer employment. Despite this link, gaps exist between these education sectors. Conference participants suggested greater collaboration and noted that community colleges and universities that share equipment or faculty have found this situation to be mutually beneficial. By building on each sectors' strengths, conference participants agreed that it is possible to develop articulation agreements from high school biotechnology courses to community colleges and from community colleges to universities. They suggested that community college faculty members could increase interest in their programs by talking with secondary school science educators, and helping them add biotechnology lessons to their usual science

University Models Biotech Program on Community College Curriculum

The University of Rhode Island's (URI) biotechnology curriculum is "stolen and modeled" on the Global Biomanufacturing Curriculum developed by the Northeast Biomanufacturing Center and Collaborative (NBC^2) at Great Bay Community College, according to Gregory Paquette, director of biotechnology and clinical laboratory sciences at the university.

This sort of replication is what the National Science Foundation expects from its Advanced Technological Education (ATE) program, which provides grants to innovative technician education programs. Curriculum and instructional materials developed with ATE grants are free to U.S. educators. Sonia Wallman is the principal investigator for NBC^2.

"Because she had developed it [the curriculum] over a number of years and fine tuned it, it really is a best practice," Paquette said, referring to Wallman.

Paquette estimates that he saved more than a year in program development time by using NBC^2's Web site and attending its summer professional development program, known as BIOMAN, with three other URI faculty members. The two baccalaureate degree programs URI offers emulate NBC^2's curriculum and use of student internships with industry.

"The community colleges are way ahead of us," he said, referring to four-year institutions' reluctance to adopt a workforce development focus. But he finds this approach gets results. His department's enrollment has grown 30% since adding the biotech options, and the job placement rate from the biotech internships is nearly 100%.

Recommendations for Faculty

Effective biotechnology programs depend on the quality of educators' knowledge, their connections with biotech employers, and their collaborations with other educators. To prepare students for biotechnology careers, the conference participants recommend that faculty members

- Develop linkages with industry.
- Participate in externships if they do not have industry experience.
- Create a culture of learning with students that involves research with an emphasis on critical thinking skills and interpreting results.
- Teach entrepreneurial skills, particularly how to take risks to achieve challenging goals and compete in the global economy.
- Inform elementary and secondary school teachers and guidance counselors about the biotechnology career pathways that begin with community college programs.
- Partner with university faculty for each institution to share their programs' strengths.
- Engage in interactive professional development activities that keep learning fun for them.

courses or by offering community college biotechnology courses at high schools.

Greg Paquette made the case that community colleges should pursue two credentialing standards: accreditation of biotechnology programs and certification of biotechnology graduates. Paquette is professor and director of biotechnology and clinical laboratory sciences at the University of Rhode Island. He pointed out that most college biotech programs already use industry standards in their curricula and argued that if community college students earn nationally recognized certifications, they will validate their credentials with employers. In this way national certification of students and national accreditation of biotechnology programs would raise the esteem of community college biotechnology programs.

Amanda Ahlstrand, director of the Business Relations Group of the Employment and Training Administration of the U.S. Department of Labor, urged educators to work with the Workforce Investment Boards in their communities to improve connections across education sectors and with regional industries. Government programs, such as the President's High Growth Job Training Initiative, provide funds to link and leverage community partners. Ahlstrand pointed out that many federal initiatives are designed to fade in and out. She urged educators to "look at the infusion of resources as starting points and run with them" so activities and programs can be sustained after government funding ends.

Julie Cooke, vice president of human resources for Invitrogen Corporation, said her company has found it worthwhile to advise

community colleges on ways to model industry practices in college courses and to offer student internships. As an employer, she looks for applicants with real-world experience and knowledge of the business side of science. She has found that people who are adaptable and communicate well and who understand the key drivers of productivity, good manufacturing practices (GMP), quality assurance and quality control (QA/QC), and the role of the U.S. Food and Drug Administration are most likely to advance in biotechnology companies that are growing with new discoveries and innovations.

Tami Goetz, science advisor to the governor of Utah, reported that Salt Lake Community College offers summer internships for faculty members to work alone or with student teams at InnovaBio, the college's contract research organization. "It's working very well because faculty are coming and working on credible commercial products," Goetz said. Another Utah professional development program takes a more light-hearted approach—such as bus tours of historically important technology sites—to build connections between high school educators and college faculty members.

Emerging Areas

Innovations that combine biotechnology with microelectromechanical systems (BioMEMS) and nanotechnology (BioNanotechnology), and those that use molecular diagnostics and microRNA were frequently mentioned by conference participants as emerging areas for the biotechnology industry. Given the rapid pace of change, the conference participants suggested that educators incorporate key aspects of emerging areas into existing biotechnician courses rather than create entirely new courses or programs. The conference participants advocated a "back to basics approach" that emphasizes the fundamental technical skills that students will need to apply when they encounter new technologies or enter niche industries.

"You cannot live without excellent manual, front-end technical skills," said Raymond Mariella Jr., senior scientist for biosecurity at Lawrence Livermore National Laboratory. Obtaining samples without contaminating them, handling materials properly, executing tests efficiently, and recording results accurately are essential whether an assay is for an ultra-sensitive advanced application or a routine process. "If you mess up the sample you are going to get the wrong answer, and you still have to understand what the answer means," he said.

Mariella said he anticipates diversification in the biotech industry as innovators combine bioscience with other sciences and engineering, and as farmers use more genetically modified crops and animals. He anticipates the biotechnology industry will grow as demand increases for genetic screening, which he expects to move to private enterprises. He also anticipates growth in individualized medicines, systems medicines, screening for drug candidates, and sample processing for food. The diagnosis and treatment of emerging diseases, such as severe acute respiratory syndrome, and drug resistant diseases will add to biotechnology's expansion. "Assays are becoming increasingly bioinformatic-centric," he said.

Innovative Partnership Includes Labs, Equipment, Courses, Faculty, Scholarships

The partnership between Newport Laboratories and Minnesota West Community and Technical College is more comprehensive than typical academic–industry partnerships. It includes facilities, equipment, scholarships, and company scientists serving as adjunct faculty and curriculum advisers.

Newport Laboratories built a 1,200-ft^2 teaching laboratory for the college at its corporate facilities about two miles from Minnesota West's Worthington campus. The teaching lab was built in 2005 about the same time the company added a 10,000-ft^2 research laboratory for its scientists at the same facility.

"When we developed our second laboratory we knew we were going to have to get involved with getting people educated. So we went to the community college system and said, 'We are going to build a new R&D facility here and we're going to give you some square footage. We'd like you to put some equipment in that we would normally put in, and provide a curriculum and instruction. We will provide adjunct instruction,'" Wayne Freese, chief executive officer of Prairie Holdings Group and its subsidiary Newport Laboratories, told conference participants.

After three years the leaders of both the college and the company report they are reaping benefits from their Bioscience Partnership, which received a statewide award in 2008. "Really good things have come out of [the Bioscience Partnership]," Freese said, explaining, "The benefits have been [that] our people are also going through the course; we've been able to hire people out of it, and now we feel we can continuously develop a workforce out of it."

Minnesota West uses the laboratory for its regular microbiology courses and its biotech technician courses, which company personnel helped faculty develop. Students and faculty use state-of-the-art equipment daily and often observe and talk with the company's technicians and scientists. These interactions have led to the addition of better investigative lab techniques in the curriculum for the associate degree in biotechnology, which includes 12 new courses.

"They're the catalyst for us in this leading edge of science," Jeffrey Williamson, vice president of instruction at the Worthington Campus, said of the company's leaders. The substantial quality of the partnership agreement, which also involves the college's agriculture programs, has given Minnesota West "the most credibility in a cutting-edge technology we've experienced in decades," Williamson said.

Sharon Presnell, vice president for Regenerative Medicine and Biology with Tengion, Inc., expects biotechnology to address unmet needs to restore or preserve the environment. Alternative fuels and products that keep food and water supplies safe were among the examples she cited. Presnell listed personalized medicines that use a patient's cells among the examples of products that generate opportunities for U.S. companies. "It's catastrophic if you mess those up; the shelf life is hours not months, and you can't do them overseas," she said. Other diagnostic, preventative, and therapeutic products with potential include tests that detect single molecules, informatics applications for complex problems, and treatments for degenerative diseases.

Bruce Leander, former president of Ambion and former vice president of Pharmacia Biotech, noted that biotechnology applications are the priority, even for funding organizations that previously provided grants for basic research. Given this trend, Leander said it is more important than ever for community colleges to ask industry what skills they need in employees and then design programs to deliver people with those qualifications. "I believe the community colleges should act like an extension of what industry is doing with teaching their employees how to be better employees and how to be more productive. If you go about it with that mind-set, you are just going to be teaching what industry needs," he said. By working with regional biotech organizations, programs can be structured to meet the particular needs of similar industries concentrated in one area.

In North Carolina, the community colleges and universities work closely with industry as part of a statewide economic development effort, according to Matthew Meyer, director of North Carolina BioNetwork for the North Carolina Community College System. The industry-education effort is working on simplifying the continuum of education to make it easier for students to navigate. It is also experimenting with infusing instruction of multiple skills in immersive learning environments—such as interactive video games—that mimic workplaces.

Toby Horn, co-director of CASE at the Carnegie Institution, said it is important that instructors have the depth of knowledge necessary to make connections for students between basic skills and emerging areas. Clearly explaining about how new applications use basic skills will help students later in the workplace when they encounter other innovations. "People don't know how to make those connections if they [the instructors] are not deeply trained," she said.

Next Steps

As intended, the lively discussions at the *Educating Technicians for Future Industry Needs* conference provided information about how biotechnology is likely to grow during the next five years and how U.S. educators can prepare technicians to meet the needs of this rapidly-changing industry. The conference participants identified promising practices and illuminated unmet educational needs throughout the meeting.

During the final plenary discussion, participants shared ideas about how biotech technician programs can work more effectively with other science and agriculture programs on their campuses. In advance of the final discussion, the conference steering committee gathered all the recommendations from the panel discussions and edited them for clarity. The lists of recommendations were then placed before the assembled participants to vote on using handheld, wireless key pads. The priorities set by the votes became the conference's final recommendations (see Recommendations on page 6).

The meeting closed with topical small-group discussions about how participants would use what they learned during the conference and how they would engage other stakeholders in education, the biotech industry, and government to carry out the conference recommendations.

It is hoped that greater collaboration among the various entities will be one outcome of the meeting because reducing demarcation and increasing cooperation are woven throughout the conference recommendations. Suggested steps to accomplish these goals include redesigning standard microbiology and biology curricula to include applications of industrial and environmental biotechnology; creating multi-disciplinary programs for cross-training faculty and students; developing biotechnology career pathways from secondary schools to community colleges and universities; and cultivating regional biotechnology industry–education partnerships.

This call to eliminate barriers was an interesting result for a conference organized by its steering committee according to the categories that industry typically uses to divide itself. This format gave participants the opportunity to learn about aspects of the industry with which they were less familiar, but it also led to consensus that every specialization and emerging area relies on technicians with strong fundamental technical skills who, because of their educational preparation, can learn new technologies and adapt to changes in the workplace.

This meeting was not intended to establish curriculum standards or to define core competencies, although both were mentioned during the discussions. It was suggested during the conference that the biotechnology industry and academic programs that prepare biotechnicians have reached the maturation necessary to develop technician certification and program accreditation processes. The conference left that as a question for the entire community of interest to consider.

Conference Participants

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