Education

Integrating PTD Into Undergraduate Curricula

By Georgi Popov, Leigh Ann Blunt, James McGlothlin, Deborah Young-Corbett, John N. Zey and Pamela Heckel

IN BRIEF
- **Undergraduate education must create a strong value proposition for students. Educators must ensure that students develop the knowledge they need not only to be competitive in the job market, but also to display necessary technical skills upon graduation.**
- **To incorporate a prevention through design (PTD) mind-set, today's students must develop the skills needed to effectively apply a PTD process.**
- **Three case studies address ways to incorporate PTD into undergraduate curricula.**

Prevention through design (PTD) aims to initiate a design process that anticipates and prevents workplace illnesses, injuries and fatalities. To mitigate and prevent work-related morbidity and mortality, it is necessary to design out hazards by assessing potential risks and subsequently developing better and safer solutions (Manuele, 2008a; 2008b). Several consensus standards provide guidance on implementation of PTD strategies (ANSI/AIHA, 2005; ANSI/ASSE, 2011). To incorporate a PTD mind-set throughout all industrial and services sectors, engineers and safety professionals must develop the skills needed to effectively apply a PTD process (Heidel & Ripple, 2012). According to NIOSH (2011):

> PTD requires the development and implementation of a broad educational framework adapted to the full range of occupational disciplines and educational settings involved in supporting the PTD initiative. The educational objectives and content will vary significantly based on the individual discipline or education setting.

To determine whether PTD principles are being incorporated into higher education, NIOSH has been tracking 1) the number of textbooks, certification examinations and standards that reference PTD concepts; and 2) the number of institutions working with NIOSH or its partners to incorporate PTD principles into curricula. Progress is being made in both areas.

Current State of PTD in Higher Education

Currently, six textbooks include PTD concepts, four are published and two are awaiting publication. One example is *The Occupational Environment: Its Evaluation, Control and Management, 3rd Edition.* While PTD is only mentioned in Chapter 1, this reflects a trend in new textbooks (Blunt, Zey, Greife, et al., 2011). Two booklets have been published, and five additional textbooks are in progress (see "Textbooks & PTD" sidebar). PTD concepts are well represented in several consensus standards as well (see "PTD Standards" sidebar, p. 46).

The number of higher education institutions that have incorporated PTD principles into their curricula is slowly increasing as well. In 2009 (baseline year), four institutions were teaching PTD principles in one or more courses; that increased to seven institutions in 2010 and 13 in 2011 (see "Institutions" sidebar, p. 47).

Mainstreaming PTD Into University Education

European Agency for Safety and Health at Work (2010) recently published "Mainstreaming Occupational Safety and Health (OSH) Into University Education," which is in alignment with the strategies that are being implemented within NIOSH's PTD initiative. The report outlines certain success fac-

Georgi Popov, Ph.D., QEP, CMC, holds a Ph.D. in Chemistry from National Scientific Board (Bulgaria) and an M.S. in Nuclear Instrumentation Building/Engineering Physics from Defense University (Bulgaria). He is an assistant professor in the School of Environmental Physical and Applied Sciences at University of Central Missouri (UCM). Popov is a member of ASSE's Heart of America Chapter.

Leigh Ann Blunt, Ed.D., is an associate professor of Safety Sciences at UCM and chair of the School of Environmental, Physical and Applied Sciences, which houses five disciplines including safety sciences. She holds an M.S. in Industrial Safety Management from UCM and an Ed.D. in Educational Leadership from University of Missouri, Columbia. Blunt is a professional member of ASSE's Heart of America Chapter.

James McGlothlin, Ph.D., CPE, is director of the graduate program in Occupational and Environmental Sciences at Purdue University. He holds a B.A. in Psychology, an M.P.H., an M.S. in Environmental and Industrial Health, and a Ph.D. in Industrial Health.

Deborah Young-Corbett, Ph.D., CSP, CIH, CHMM, is an assistant professor of civil and environmental engineering at Virginia Tech, where she has established an integrated research and education program emphasizing PTD solutions for the control of construction health hazards. She holds a B.S., M.S. and Ph.D. from Virginia Tech, and an M.S. from North Carolina State University.

John N. Zey, Ed.D., CIH, is an associate professor in the School of Environmental, Physical and Applied Sciences at UCM. He holds a B.S. in Biology and an M.S. in Industrial Hygiene from UCM, and an Ed.D. in Educational Leadership from University of Missouri, Columbia. He is a professional member of ASSE's Heart of America Chapter.

Pamela Heckel, Ph.D., P.E., is a senior service fellow at NIOSH, where she develops educational outreach materials for the Prevention Through Design initiative. Heckel holds a B.S. in Engineering from Vanderbilt University, a B.S. in Civil Engineering from Purdue University, and an M.S. in Architecture and a Ph.D. in Environmental Engineering from University of Cincinnati.

tors associated with embedding OSH into university curricula, some of which relate specifically to integrating PTD into undergraduate education:

•Start by finding and engaging receptive individuals and institutions.

•Work in cooperation. Do not be prescriptive.

•Be sensitive to competing curriculum demands and existing pressures on undergraduate time.

•Limit OSH teaching to certain key aspects.

•Embed OSH issues within courses rather than as an add-on.

•Provide suitable OSH educational materials that are relevant to the study area into which they are being embedded and the way that topic is taught.

•Use real cases and look for ways to introduce problem-solving methods, active learning and similar methods.

•Provide assistance to academics in how to make effective use of the materials.

•OSH skills are developed not only through theoretical classes but also by performing practical risk analysis activities based on real-world work situations from different fields of activity according to each student's vocational area.

•For student motivation, have the study of OSH contribute to final grades or attainment of a recognized diploma.

Textbooks & PTD

Published Textbooks Containing PTD

•*Advanced Safety Management: Focusing on Z10 and Serious Injury Prevention, 3rd ed.*, by Fred A. Manuele, 2008, Hoboken, NJ: John Wiley & Sons.

•*Water Supply and Wastewater Removal: Fair, Geyer and Okun's Water and Wastewater Engineering, 3rd ed.*, by Nazih K. Shammas and Lawrence K. Wang, 2011, New York, NY: John Wiley & Sons.

•*A Brief Introduction to Fluid Mechanics, 5th ed.*, by Donald F. Young, Bruce R. Munson, Theodore H. Okiishi and Wade W. Huebsch, 2010, New York, NY: John Wiley & Sons.

•*Engineering Mechanics and Design Applications: Transdisciplinary Engineering Fundamentals*, by Atila Ertas, 2012, Boca Raton, FL: CRC Press, Taylor & Francis Group.

Textbooks That Include PTD Concepts Ready for Publication

•*Waste Treatment in the Mining and Chemicals Manufacturing Industries*, edited by Lawrence K. Wang, Nazih K. Shammas and Yung-Tse Hung, John Wiley & Sons.

•*Advanced Biological Treatment Processes (Volume 9, Industrial and Hazardous Wastes)*, edited by Lawrence K. Wang, Nazih K. Shammas and Yung-Tse Hung, John Wiley & Sons.

Published Booklets Containing PTD

•*Transdisciplinarity: Bridging Natural Science, Social Science, Humanities and Engineering*, edited by Atila Ertas, 2011, USA: TheATLAS Publishing.

•*Prevention Through Design: Transdisciplinary Process*, by Atila Ertas, 2010, USA: TheATLAS Publishing.

Current Textbook Projects

•*Design of Reinforced Concrete,* by Jack C. McCormac and Russell H. Brown, 2013, New York, NY: John Wiley & Sons.

•*Elementary Principles of Chemical Processes*, by Richard M. Felder, 2012, New York, NY: John Wiley & Sons.

•*Unified Design of Steel Structures,* by Louis F. Geschwindner, 2013, New York, NY: John Wiley & Sons.

•*Heat and Mass Transfer: Fundamentals and Applications*, by Afshin J. Ghajar, 2013, New York, NY: McGraw-Hill.

•*Human Factors Design Handbook*, by Barry Tillman, 2013, New York, NY: McGraw-Hill.

Case Descriptions

Three case studies provide examples of various strategies for incorporating PTD concepts in undergraduate engineering curricula (Purdue University and Virginia Tech) and safety science curricula (University of Central Missouri).

Purdue University, West Lafayette, IN

While several engineering departments at Purdue University have integrated PTD into their curricula, including industrial, mechanical, electrical, and aeronautics and astronautics, the civil engineering curriculum stands out. The technical electives in this discipline were evaluated to obtain an emphasis in architectural engineering, general civil engineering, construction engineering, environmental engineering, geomatic engineering, geotechnical engineering, materials engineering, structural engineering, hydraulics and hydrologics, and transportation and infrastructure systems engineering. In total, more than 156 courses are offered, two in earth and atmospheric sciences, six in mechanical engineering, four in entrepreneurship, and one each in construction engineering management, management and chemistry that are included in the emphasis curricula.

In addition to civil engineering, the construction engineering management (CEM) curriculum was examined. This course of study prepares undergraduate engineers to serve in dual roles as both engineer and manager. Through the CEM curriculum, students can select either a mechanical or electrical plan of study. Incorporating PTD into the CEM curriculum is crucial as expressed in a June 2003 letter from the head of the CEM program to students:

> Finally, students should consider the following list of special knowledge and skills which mechanical/industrial contractors often require. Few of these topics will be available in Purdue courses, and students should seek ways to gain knowledge in these areas during internships or through other means (e.g., construction safety in industrial and mechanical construction operations).

To evaluate the curriculum, a course was tagged if its title suggested the potential to include PTD in the course structure. Using this method, 23 courses were tagged in civil engineering curriculum and 12 courses were tagged in CEM curriculum. Next, the syllabi and course schedules were evaluated for PTD-related lectures and course objectives. This process allows for better utilization of courses to meet curricular needs associated with PTD.

To complete modules that would be both interesting and relevant to students, case studies and examples were selected. The 200 MW Meadow Lake Wind Farm project in White County, IN, was completed with zero lost-time incidents due in part to built-in fall protection systems. The facility received two prestigious awards: The Aon Build America Award and an Indiana ACI Outstanding

PTD Standards

Published PTD-Related Standards

- ANSI/AIHA/ASSE Z10-2012, Occupational Health and Safety Management System
- ANSI/ASSE Z590.3-2011, Prevention Through Design: Guidelines for Addressing Occupational Hazards and Risks in Design and Redesign Processes
- SAE J2194, Roll-Over Protective Structures for Wheeled Agricultural Tractors
- ANSI B11.0, Safety Standards for Machine Tools
- ANSI B11.19, Performance Requirements for Safeguarding
- ISO 12100, Safety of Machinery—General Principles for Design—Risk Assessment and Risk Reduction
- ANSI/PMMI B155.1, Safety Requirements for Packaging Machinery and Packaging-Related Converting Machinery

Standards in Progress

- ASHRAE 9.11, Clean Spaces
- ANSI B11, Safety Standards for Machine Tools
- ISA 12, Electrical Equipment for Hazardous Locations
- UL 2201, Portable Engine—Generator Assemblies
- ANSI/ISEA Z87, Safety Standards for Eye Protection
- ANSI/AIHA/ASSE Z9, Ventilation Systems Standards
- ANSI A10, Safety in Construction and Demolition Operations
- ASHRAE 161, Air Quality on Commercial Aircraft

Achievement in Concrete Award. Through the example, students can relate the theory covered at the beginning of the module to an industry scenario.

Case studies are another crucial learning tool. Via multimedia video presentations, students view various video clips that explain the uninterruptable power supply and the acid exhaust gas scrubber found at the Birck Nanotechnology Research Center on campus. Students see and hear about the systems' designs, then identify PTD elements. The education modules help students develop knowledge of safety and health concepts to prevent injuries and save lives.

To sustain the PTD initiative at Purdue, the dean of engineering formed a committee composed of faculty from all disciplines. Called the Engineering 2020 Committee, the group's charge is to "provide educational experiences that develop students' knowledge areas, abilities and qualities to enable them to identify needs and construct effective solutions in an economically, socially and culturally relevant manner." To this end, in 2011 the colleges of Engineering, Health and Human Sciences, and Technology partnered with NIOSH to deliver a workshop, Prevention Through Design: Designing a Safer Tomorrow Through Engineering Today. The workshop raised awareness among faculty and students about incorporating safety and health into design. More than 45 posters were submitted for review and evaluation, and the student authors of the top three gave platform presentations. The idea is to promote PTD through student- and faculty-driven applied research. The initiative's website (**https://engineering.purdue.edu/Intranet/Groups/Committees/Engr2020/Workshops/2011Workshop**) provides case studies for faculty to use in course development. In other words, Purdue University is solidly behind PTD.

Virginia Tech, Blacksburg, VA

A course developed in 2007 and taught in the Virginia Tech Myers-Lawson School of Construction presents PTD concepts to a multidisciplinary student body composed of those majoring in civil engineering, architecture and building construction. The course covers hazard recognition and PTD design solutions for chemical and physical health hazards, and major safety hazards associated with construction operations, such as falls, excavations, heavy equipment, cranes and fire.

Students learn to design construction materials, tools, equipment and processes from a PTD perspective. They also learn about material substitution, wet methods, ventilated tools and isolation systems to control chemical health hazards. PTD solutions for physical health hazards include solid vibration damping, air turbulence control and distance attenuation for noise control. For vibration hazards, the course covers methods of vibration reduction and seat, tool and glove design. Ergonomic solutions, such as panelization, prefabrication and automation, are also reviewed. To address risks from excavation operations, the course covers basic soil mechanics and methods of designing sloping, benching and support systems.

Classroom instruction provides in-depth information regarding the design of both passive and active fall protection and arrest systems. The course reviews innovative engineering solutions for heavy equipment and crane hazards such as autonomous vehicles, visualization systems and proximity-sensing devices. Finally, in the fire design module, students learn basic design techniques for structural resistance and stability, fire movement control and fire protection (detection, signaling and suppression) (Young-Corbett, 2011).

Several pedagogical modalities are employed in delivering this course. Through lecture and literature study, students learn of existing PTD solutions for construction hazards, as well as those currently being investigated. Through participatory design team processes, students become engaged in the innovation process by conceptualizing and developing PTD solutions of their own. Through guest lectures, students get a glimpse into state-of-the-art PTD research activities ongoing at Virginia Tech.

University of Central Missouri, Warrensburg, MO

PTD became an integral part of undergraduate academic courses at University of Central Missouri (UCM) in early 2009. PTD terminology and concepts are introduced in lower-level safety courses, then covered in greater detail in later courses. More complicated educational modules and models are used in senior-level courses to enhance critical-thinking skills and challenge students not only to identify problems, but also to recommend solutions that meet a company's legal, ethical and fiscal responsibilities.

For example, in environmental compliance, students engage in discussions and analysis of actual case studies, including *Deepwater Horizon* and its lack of safeguard systems. Students analyze system failures associated with inadequate or nonexistent understanding and application of PTD during the design phase. In the required statistics course, students practice utilizing chemical exposures and prevention methods. Various spreadsheet-based tools were developed to aid students in making correct PTD recommendations and applying the appropriate measures from the hierarchy of controls. Cost-benefit analysis and industrial hygiene value strategy are also incorporated into the learning activities.

Unfortunately, few comprehensive safety-related textbooks include PTD-related chapters. As a result, UCM safety sciences faculty developed course materials and tools based on PTD standards as supplemental material that could be provided to students (e.g., ANSI/ASSE Z590.3-2011, Prevention Through Design: Guidelines for Addressing Occupational Hazards and Risks in Design and Redesign Processes). For example, risk assessment is a critical component of PTD. Safety professionals should become familiar with and participate in product/equipment development, life-cycle assessments, risk assessment, engineering design and risk reduction principles. PTD models were developed to demonstrate the effectiveness of PTD elimination, avoidance and engineering hierarchy of controls. The models were successfully used in ergonomics courses and capstone courses (Popov, 2011).

One preliminary hazard analysis tool presents opportunities to lower risk. A tracking log is added to enhance PTD contributions. Students review real-world examples and are required to recommend PTD actions and discuss risk assessment code reduction based on those recommendations. Failure mode and effects analysis (FMEA), which is introduced in systems safety and statistics classes, requires entry of probability, severity and risk priority codes. Students receive an FMEA form on which those codes would be entered. These tools are used as statistical exercises in the risk management class, which attract majors from industrial management, aviation safety and environmental science. Spreadsheet-based PTD and FMEA tools were successfully used in a new food safety class as well. With ANSI's Technical Report on Designing for Safety and Lean Manufacturing, information on how PTD principles can be integrated with common industrial management practices can be utilized in curriculum outside of that offered by the Safety Sciences department.

During fall semester 2011, UCM approved funding for the development of a sustainability and safety course. Course materials are extensively based on the PTD standard and cover engineering, risk assessment/risk management, business continuity and sustainability. The course is intended to attract undergraduate as well as graduate students from different disciplines.

UCM is creating a new paradigm to accelerate attainment of an undergraduate degree. This concept brings together various partners for an innovative project that promotes decreased time to a degree, decreased or no student loan debt, and a guarantee that students who complete the program will graduate with the skills to meet industry needs. Missouri Governor Jay Nixon had this to say following a planning meeting among various partners in this initiative:

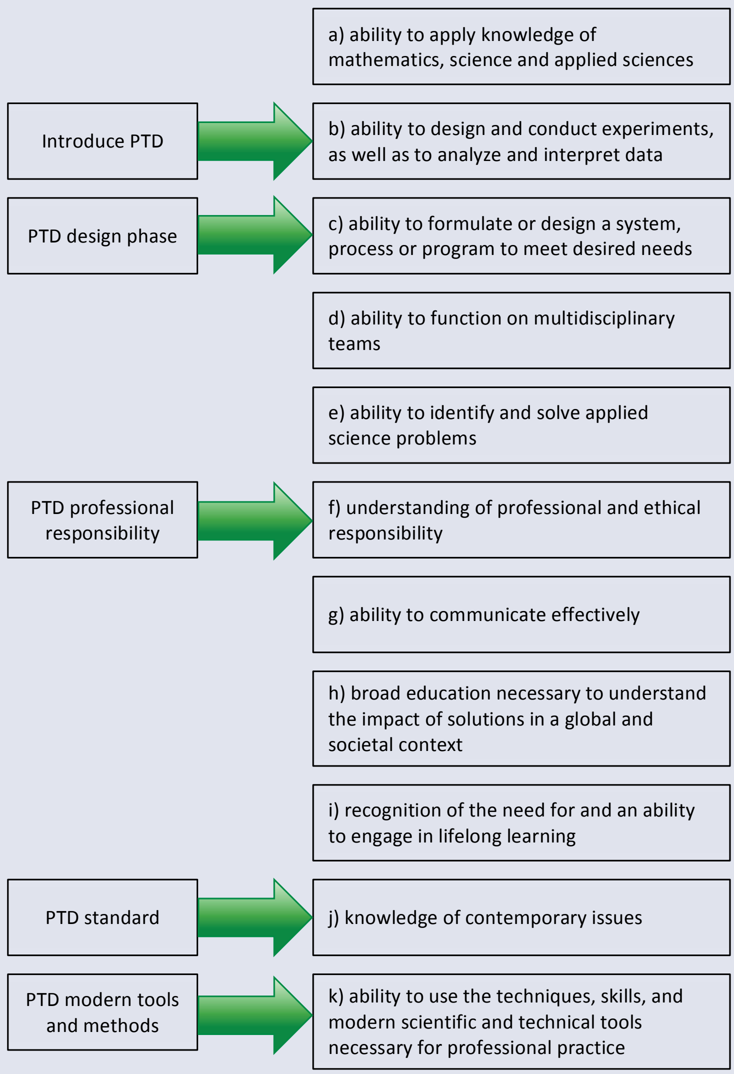
> Sitting with [UCM President Chuck Ambrose] and all the business leaders when we met over in Lee's Summit was just impressive. He had the business leaders there, the community college folks there, talking concretely about what we can do to get kids jobs, to get companies invested in higher education, and a lot of credit goes to Chuck Ambrose. (Nixon Takes UCM Idea Statewide, 2012)

Successful interdisciplinary teams will combine students and professionals from safety, industrial management, computer technology, business and industrial hygiene. Such a synergy among businesses, high schools, undergraduate university pro-

Institutions of Higher Learning With PTD Incorporated Into Curricula

Bucknell University
Harvard University
Oregon State University
Purdue University
Texas Tech University
University of Alabama at Birmingham
University of California, Los Angeles
University of Central Missouri
University of Florida
University of Massachusetts Lowell
University of Utah
Virginia Commonwealth University
Virginia Tech

Figure 1
ABET General Criterion 3: Student Outcomes & Possible PTD Introduction



grams and engineering firms presents enormous opportunity to include PTD concepts in early design stages and helps bring theory and practice together.

PTD-based certificate educational programs could also be developed in the future. Such programs will attract working professionals, students from different disciplines and even educators. Successful partnerships could be developed between educational institutions and OSHA training institutes. PTD modules and courses could be developed to meet the needs of state OSHA programs as well.

ABET PTD Opportunities

Graduates from accredited programs have enhanced opportunities for employment and professional recognition. Currently, the graduate safety practitioner (GSP) designation is available to safety graduates from degree programs that meet BCSP's Qualified Academic Program (QAP) standards. At present, BCSP defines a QAP as a bachelor's or master's degree program holding program accreditation as a safety or safety-related program by the Applied Science Accreditation Commission of ABET (ASAC/ABET) or the Aviation Accreditation Board International (BCSP, 2011).

As of 2012, only eight baccalaureate safety programs are ABET accredited. ABET accreditation presents real opportunities for inclusion of PTD through its program criteria, particularly the criterion associated with student outcomes. Figure 1 identifies ABET requirements associated with student outcomes and overall program criteria and how PTD can be incorporated to assist in meeting the criteria. Figure 2 presents program criteria PTD opportunities.

Conclusions

It has been said, "Good design is obvious. Great design is transparent" (Joe Sparano, Oxide Design Co.). Likewise, article coauthor James McGlothlin says:

> PTD need not be apparent, nor obtrusive, nor appear as an add-on, if so, it will not last. For something to be designed that is inherently safe and healthy, pleasing to the eye, has ergonomic features that make it easy to use and/or operate, is well built to withstand the day-to-day demands of its form and function and is affordable, then anything that has PTD as its foundation is truly a creation that will blossom from idea to icon.

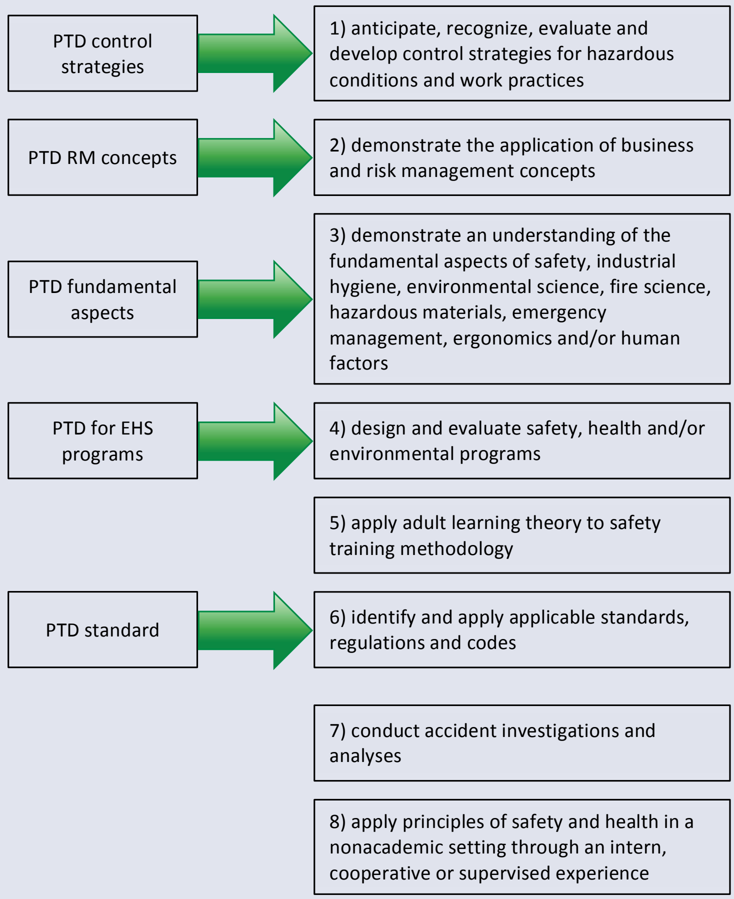
NIOSH has engaged the nation through its PTD initiative, from industry to labor to professional associations (such as ABET) to academia. Particularly, NIOSH has captured the attention of academia because it has recognized the need to plant the seeds of PTD in the minds of today's students and faculty who will build tomorrow's world.

The lists of programs and institutions teaching PTD and conducting related research in this article is not exhaustive. Hundreds of institutions may be conducting similar work. What is important is that the universities sustain this initiative and make it relevant for future engineers and safety professionals. Having qualified faculty members is a key component to achieving this goal. Faculty expertise will vary by program and should include P.E.s in the engineering programs and CSPs and CIHs in the multidisciplinary safety-based programs.

More than ever, undergraduate education must create a strong value proposition for students. As young adults transition from high school to college to career, educators must close the skills gap so that the students develop the knowledge they need not only to be competitive in the job market, but also to display necessary technical skills from the day they graduate. Education's challenge is to extend far beyond the traditional lecture hall to a place where students are actively engaged and immersed in the learning process. **PS**

Figure 2

ABET UG Program Criteria



References

ABET. ABET-accredited safety undergraduate programs. Retrieved from **http://main.abet.org/aps/Accreditedprogramsearch.aspx**

ANSI/AIHA. (2005). Occupational health and safety management systems (ANSI/Z10-2005). Fairfax, VA: Authors.

ANSI/ASSE. (2011). Prevention through design guidelines for addressing occupational hazards and risks in design and redesign processes (ANSI/ASSE Z590.3-2011). Des Plaines, IL: Author.

Blunt, L.A., Zey, J.N., Greife, L., et al. (2011). History and philosophy of industrial hygiene. In D. Anna (Ed.), *The occupational environment: Its evaluation, control and management* (3rd ed.). Fairfax, VA: AIHA.

BCSP. (2011). GSP criteria. Retrieved from **www.bscp.org/GSP**

European Agency for Safety and Health at Work. (2010). Mainstreaming occupational safety and health (OSH) into university education. Retrieved from **http://osha.europa.eu/en/publications/reports/mainstream_osh_university_education**

Heidel, D.S. & Ripple, S.D. (2012, April). Closing the exposure gap. *The Synergist, 23*(4), 22-23.

Manuele, F.A. (2008a). *Advanced safety management: Focusing on Z10 and serious injury prevention.* Hoboken, NJ: John Wiley & Sons.

Manuele, F.A. (2008b, Oct.). Prevention through design: Addressing occupational risks in the design and redesign processes. *Professional Safety, 53*(10), 28-40.

National Academy of Engineering. (2004). *The engineer of 2020: Visions of engineering in the new century.* Washington, DC: National Academies Press.

NIOSH. (2010). NIOSH releases prevention through design (PTD) plan: Transformative goals, strategies for job safety and health. Retrieved from **www.cdc.gov/niosh/topics/ptd**

NIOSH. (2011). NIOSH PTD goals. Retrieved from **www.cdc.gov/niosh/programs/PtDesign/goals.html**

Nixon takes UCM idea statewide. (2012, Feb. 10). *The Daily Star Journal.*

Popov, G. (2011). PTD Model 3.0: Faculty research. Warrensburg, MO: University of Central Missouri. Retrieved from **http://centralspace.ucmo.edu/xmlui/handle/10768/109**

Young-Corbett, D. (2011). Inclusion of PTD into engineering education. Presentation at Prevention Through Design—A New Way of Doing Business: Report on the National Initiative, Washington, DC, Aug. 22-24. Retrieved from **www.cdc.gov/niosh/topics/ptd/a-new-way/agenda.html**

For More Information

All presentations from NIOSH's 2011 PTD conference are available at **www.asse.org/professionalaffairs_new/ptd.php**.