Teaching Sustainability: Course, Program and Degree Considerations

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Abstract--In recent years within the United States, sustainability has gained importance in higher education, government agencies, business and industry, and in the general public's consciousness. The goal of meeting today's needs without harming future generations' ability to realize their potential is the hallmark of sustainable practices, and there is widespread interest from many disciplines and sectors in developing, enhancing, and integrating sustainability into aspects of products, services, and solutions. Thus, the need to equip students with the knowledge, skills, and perspectives to make contributions to sustainability initiatives and processes has never been greater.

Sustainability can be taught in many disciplines, including, but not limited to: design, engineering, manufacturing, technology, and management. This paper outlines how sustainability can be taught in these areas, and how sustainability might be integrated into the curriculum from three perspectives: course, program and degree. At the course level, examples of how to integrate the concepts and applications of sustainability into existing material will be discussed. Program-level considerations for teaching sustainability will also be examined. The current situation and the demand for a sustainable knowledge in the workplace and how that might lead to a sustainable degree will be addressed. An inventory of green jobs and careers will be investigated and how sustainable courses, programs and degrees can support the future global workforce and address stakeholder's needs wants and expectations in a sustainable, low carbon world.

I. WHY TEACH SUSTAINABILITY?

The global challenges relating to issues such as food, water, environment, energy, health and so many more have never been more prominent in the United States than they are today. Engineers and technologist are problem solvers and should be addressing these issues in sustainable ways. The National Academy of Engineering (NAE) received a grant from the National Science Foundation to form a committee and gather information from engineers and engineering educators on the grand challenges that face the world today. Some of those challenges have been identified. To make solar energy affordable and provide everyone with access to clean water are just two of a list of 14 that were developed by an appointed committee. [11] However, the NAE is looking for input from engineers, engineering educators, scientist, and researchers interested in sending in their ideas for this, as well. The NAE is running a number of workshops on this topic to further flush out the list. Whatever the final list of global challenges becomes, it is clear that our current and future engineering and technology students will need to be educated in sustainable development skills knowledge and skills in order to solve the problems of today and tomorrow in sustainable manner.

Sustainable development is a contemporary issue for everyone to embrace, especially engineers, engineering technologist, architects, designers, manufacturers, etc. Sustainable development is common practice in European Union and many other developed countries; however, the concept has not been mainstreamed into engineering education within the U.S. Several engineering societies within the U.S. have made declarative statements about their commitments to sustainable development. In 2002, the American Association of Engineering Societies, American Institute of Chemical Engineering, American Society for Mechanical Engineers International–Environmental Engineering Division, National Academy of Engineering, and the National Society of Professional Engineers made a declaration to the World Summit on Sustainable Development held in Johannesburg, South Africa, to commit to creating a sustainable world.[7] In 1999, the American Society for Engineering Education (ASEE) Board of Directors approved the following statement," ASEE believes that engineering graduates must be prepared by their education to use sustainable engineering techniques in the practice of their profession and to take leadership roles in facilitating sustainable development in their communities." [1] The National Academy of Engineering addresses sustainable development issues by supporting research and publishing reports on sustainability including: *Sustainable Federal Facilities: A Guide to Integrating Value Engineering; Life Cycle Costing, and Sustainable Development; Harnessing Ingenuity for Sustainable Outcomes, Technology and Sustainable Development*; and *Sustainable Development and Systems Engineering*. The American Society of Civil Engineers (ASCE), the American Society for Engineering Education, and the American Institute of Chemical Engineers (AIChE) joined together to co-sponsor a forum on Sustainability whose mission was to help promote the principles and practice of sustainability.[3] While all of this is a good beginning, it falls short of having sustainability taught in engineering education.

Germany is an excellent example of a country that practices sustainability. For over thirty years, industry and business have had numerous laws and regulations concerning environmental issues and practices. Sustainability is even part of the German culture. The subject of sustainability is taken very seriously by the European Union (EU), it is the government and industry's response to climate change, dwindling natural resources, and social responsibility.[4]

According to Paul Hawkins, the author of the *Ecology of Commerce A Declaration of Sustainability*, the single most important damaging aspect to destroying the earth, in the past and now, is the failure of a company to include the cost of replacing the product or process it takes from the earth.[6] In the EU and Germany these kinds of costs are routinely taken into account along with the costs to society. The "triple bottom line" has been the norm in German business for many years. In 2000, a Forum for Sustainable Development of German Businesses was started by 23 global companies to integrate "econsense" an effective framework to strengthen the exchange of information on sustainable development and corporate social responsibility, and raise the levels of competence in these important areas. Sustainability focuses on balancing societal, environmental and economic stewardship. [2]

II. INTEGRATING SUSTAINABLE CONCEPTS IN COURSES

It is easy to imbed sustainable modules into existing engineering, technology or management courses. Some examples of these modules or topics are listed in Table 1.

TABLE 1. EXAMPLES OF SUSTAINABLE MODULES IMBEDDED IN COURSE

Discipline	Examples of sustainable modules imbedded in courses
Architecture, Design, or Manufacturing	Bio-mimicry related to sustainable design and product development and design using recycled material
Engineering and Engineering Technology	Renewable energy, wind turbine technology, solar energy technology, and energy conservation practices in commercial, industrial, and residential environments
Architecture, Design, Civil	Green design, green roofs and other construction-related sustainable design and computer aided energy simulation
Manufacturing	Sustainable development in manufacturing processes (e.g., new automotive painting methods, healthy indoor air quality for workers, cradle-to-cradle concepts for materials resource maximization)
Technology	Analysis of new innovative technologies that support sustainable practices in specific industries and organizations
Management, Leadership, Ethics	Change management practices in creating, implementing, and nurturing a culture of sustainable practices; green to gold concepts
Public Policy	Building design codes, energy consumption, and recycling issues; new laws and regulations - European Union regulations and LEED standards

The easy part is to identify a discipline and integrate concepts and applications of sustainability into an existing course. Many faculty are just not aware of what sustainability is about or how it relates to their discipline. The difficult part is to capture the attention of the faculty member and to make them aware of sustainability concepts and practices in their area and why it is important for solving problems today and in the future.

A great example of how this can be handled on a campus level is happening at Missouri State University (Springfield). The 2008-09 public affairs theme for the campus is sustainability. During the academic year the campus will celebrate the sustainability theme in various ways. The theme year events and discussions will conclude with a three day conference with experts on sustainability, environment, and economics. These experts from around the US and the world will discuss sustainability in an open forum. The campus will host a series of workshops that deal with incorporating sustainability into the curriculum. Faculty who already incorporate sustainability in their courses will work with faculty who are new to the topic and are looking for ways to incorporate sustainability into their own courses. At Missouri State, sustainability is being developed as a cornerstone principle for a course that all freshman will be required to take. [10]

Another difficult area, according to Kevin Coyle, Vice President Education and Training for the National Wildlife Federation, is that by nature higher education is sharply divided by disciplines that tend toward broad system oriented thinking about societal and environmental problems and therefore don't see the relationship. He suggested, "You almost need an ombudsman to say, are you paying attention to this because that is related to this over here."[10] In other words, sustainability interconnects many disciplines. It is a great way to collaborate with colleagues in other disciplines and it breeds innovation. Many sustainable development projects have given birth to new products and businesses.

There are opportunities for engineering and technology faculty to attend National Science Foundation (NSF) sponsored summer workshops to learn how to incorporate sustainable modules into their current courses or to develop an entire sustainable course. These workshops help faculty to improve their courses, obtain funding for educational innovations, and become part of a growing network of educators in Sustainable Engineering. For the past two summers, these workshops have been offered by the Center for Sustainability, which is run by faculty from Carnegie Mellon University, the University of Texas at Austin, and Arizona State University.

III. SUSTAINABLE DEGREE PROGRAMS

With the rising cost of energy and issues of global warming, businesses have joined students in demanding that schools pay closer attention to issues of sustainable development. Many business schools have MBA programs

specifically dedicated to sustainability or concentrations in this area. Albert H. Segars, Director of North Carolina's Center for Sustainable Enterprise says, "More students are entering business with an eye toward making the world a better place." [9]

The same is happening in engineering and technology. The dean of the College of Architecture at the University of Arizona said that more students today are spending their green on a greener education. His faculty are collaborating with the School of Natural Resources to offer environmental courses, a trend which seems to be holding true nationally. "There is a sense of urgency that's never been there before," Cervelli said, "and young people are looking to the future with a sense of purpose. I haven't seen anything like it since the original Earth Day in the 1970's, regarding the overall environmental movement." The School of Management at Arizona University is also building sustainability into their program. They will teach corporate social responsibility, energy, and environment. The School of Engineering has multiple degrees related to sustainability; Biosystems Engineering, Hydrology, and Chemical Engineering. [9]

Faced with a growing demand for graduates knowledgeable in sustainability, Oregon Institute of Technology is adding sustainable courses to its current Bachelor of Science Environment Degree. Students will be taking courses in build environment, renewable energy, and fuel cells technology to mention just a few, which will be taught by engineering and engineering technology faculty. The Director of the Environmental degree program said, "OIT graduates in this program will not only be able to identify key elements of complex programs, they will have exposure to new sustainable technologies to help solve them." [5]

IV. A SUSTAINABLE REPORT CARD

The National Wildlife Federation (NWF), Princeton Survey Research Associates International, and NWF Campus Ecology with numerous other co-sponsors support a comprehensive national campus survey called, "Campus Environment 2008: A National Report Card on Sustainability in Higher Education." The 2008 survey was the second in a series on nationwide surveys that was designed to track trends and advances in environmental stewardship, sustainability activities and related curricular offerings in higher education. The first survey was reported in 2001. All 50 states participated in the 2008 survey as well as 1,068 institutions, which is 27% of US colleges and universities [10].

In the Forward, Kevin Coyle, Vice President, Education and Training National Wildlife Federation, indicted that comparisons of the 2001 data to 2008 data showed positive changes occurring in the greening of campuses, however, it also showed that between the years 2001 and 2008 the amount of sustainable related education offered on campus declined. Coyle goes on to conclude that the students of today will lead our businesses, educational institutions and government agencies. These students need a type of education that will prepare them for a world of new and cleaner forms of energy production, transportation, agriculture, natural resources management, health care, new technologies, etc. Kevin said, "To achieve this at the speed required will call for serious new support including new guidance and funding from federal and state governments, and a complete rethinking of how we educate every degree candidate from architecture and engineering to accounting and even teaching itself." [10]

The report indicated that from 2001 to 2008, the number of programs to support faculty professional development on environmental or sustainable topics had decreased. In 2001, 8% of students took a course related to the environment or sustainable topic and in 2008 the percentage dropped to 4%. The good news from the report was that there was a commitment from university leaders to do more (setting and reviewing sustainable goals, staffing sustainable programs, and orienting students, staff, faculty) in the sustainable area. The other bright note in the survey indicated that campus leaders were much more likely to rank environmental and sustainability programs among their highest priorities and that competing priorities are no longer the obstacles that they were in 2001. [10]

V. SUSTAINABLE GREEN CAREERS

Students who at least have some knowledge of sustainability related to their discipline can be winners in obtaining careers in the new green jobs market. Using the University of Arizona as an example, students who learn biosystems engineering apply engineering skills to plants and animals; manage wastewater and ecosystems; and understand water issues (i.e., erosion, fire sensitivity to drought). These graduates work at consulting firms or for the state or federal agencies (EPA). Students who learn hydrology and apply chemistry, physics, and calculus to study surface and ground water, water systems, reactions and hydrometeorology graduate working at state or federal agencies, consulting groups, and nature conservancies. Students who learn business administration and the impact of energy and the environment work at business or environmental consulting agencies and government agencies. Architecture and landscape students learn to build energy efficiency and water conservation into design and materials. These graduates work at sustainable private or public architectural firms. Students who earn a degree in chemical engineering and learn about water treatment, air pollution, hazardous waste treatment, biodegradation of hazardous materials, and create environmental impact statements. These graduates work for NASA, various industries, and municipal, state, and federal government agencies These are just a few examples of what kind of current degrees supplemented with sustainable courses, would allow graduates enough sustainable

knowledge to gain positions in a "green or sustainable job' upon graduation.[9]

VI. SUSTAINABLE DEGREES

In addition to offering separate courses in sustainability to students, the University of Arizona offers two stand alone degrees in sustainability. One is a Bachelor of Arts in Sustainability. Students pursuing this degree choose to follow one of four tracks; society and sustainability; policy and governance in sustainable systems; international development and sustainability; and sustainable urban dynamics. The other sustainable degree is a Bachelor of Science in Sustainability. Students pursuing the BS degree must choose from three tracks: sustainable energy, materials and technology; economics of sustainability; and sustainable ecosystems. Both of these degrees are housed in a new School of Sustainability.

Other universities that currently offer sustainable degrees are St Petersburg College which offers a BS in Sustainable Management and Appalachian State University which offers four sustainable degrees; BA in Sustainable Development; BS in Sustainable Development in Agroecology and Sustainable Agriculture; BS in Sustainable Development in Community, Regional and Global Development; and BS in Sustainable Development in Environmental Studies.

Sustainable degrees are new and will be more common in the next couple of years. Currently, the authors are working on a BS in Sustainability, which will focus in three areas: renewable energy, green building, and sustainable design. A goal is to have students sit for the Leadership in Energy and Environmental Design (LEED) exam and the Certified Energy Manager (CEM) exam when they complete their degree or sometime during their career. The degree will be housed in a School of Engineering and Technology as a Bachelor of Science in Sustainability. Faculty are collaborating with two other schools on campus to develop this degree program; the School of Science and the School of Public and Environmental Affairs. Courses from the environmental science and pubic and environmental affairs departments will be utilized in the degree program. Within the Technology side of the School, three departments are collaborating to bring the degree forward. At this date the degree has not been presented to the Chancellor for approval as one of the first steps before embarking on the path of numerous other approval points. The dean and department chairs have approved the faculty to work on a document that will be presented to the Chancellor, for his approval before the real approval processes can begin. Currently, the faculty are working with industry leaders to get their input and so far it has been very positive. The right courses need to be offered so that graduates will be employable in several green industries when they graduate. Table 2 is a draft of the proposed degree.

TABLE 2. DRAFT OF COURSES FOR BS IN SUSTAINABILITY

DRAFT	**Bachelor of Science in Sustainability**	
Existing Course Number or New FRESHMAN LEVEL COURSES	**Title of Course**	**No. of Credit Hours**
First Semester (15 Hours Required.)		
NEW -TECH 2	Introduction to Sustainable Principals and Practices	3
ENG W131	Elementary Composition I	3
TECH 105	Introduction to Engineering Technology	1
GEOL-G 1	Climate Change	1
COMM R110	Fundamentals of Speech Communication	3
MATH 153	Algebra and Trigonometry I	3
	Total	15
Second Semester (18 Hours Required.)		
NEW -TECH 2	Industrial Waste Management	3
GEOL-G 2	Water Resources and Conservation	3
NEW= Geology	Environmental Impact Assessment	3
MATH 154	Algebra and Trigonometry II	3
NEW TECH 2	Sustainable sites	3
H or SS Elective	Humanities or Soc. Sc. Elective	3
	Total	18
SOPHOMORE LEVEL COURSES		
Third Semester (18 Hours Require.)		
NEW- TECH 3	Building Information Modeling Simulation	3
MATH 221	Calculus for Technology 1	3
OLS 27400	Supervisory Management	3
TCM 220	Technical Report Writing	3
GEOL-G 3	Global Warming Science	3
Intro to Statistics	IET 15000, Econ E270, CIT 1200, or stat 301	3
	Total	18

Fourth Semester (18 Hours Required.)		
NEW -TECH-3	Economics and Leadership Aspects of Sustainability	3
NEW- TECH 3	Renewable Energy Technologies	3
NEW -TECH 3	Green Building -LEED	3
OLS 252	Human Behavior in Organizations	3
NEW- TECH/SPEA	Cost Benefit Analysis of Sustainable Decisions	3
SPEA	Environmental Health Technology- Managing Water and Waste	3
	Total	18
JUNIOR LEVEL COURSES		
Fifth Semester (18 Hours Required.)		
NEW -TECH	Green Building: Project Planning and Cost Estimating	3
NEW -TECH	Energy Efficiency in Industry	3
NEW -TECH	Technical Elective	3
New SPEA or PE	Sustainable Lifestyles	3
IET 35000	Engineering Economy	3
H or SS Elective	Humanities or Soc. Sc. Elective	3
	Total	18
Sixth Semester (15 Hours Required.)		
NEW- TECH	Sustainable Building Systems	3
NEW- TECH 3	International, Industry and Case Study Perspectives in Sustainability	3
New TECH	Technical Elective	3
SPEA -E451	Air pollution and Control	3
TCM 320	Written Communication in Science and Industry	3
	Total	15
SENIOR LEVEL COURSES		
Seventh Semester (6 Hours Required.)		
NEW -TECH 3	Required Internship	3
NEW -TECH 3	Directed Studies in Sustainability	3
	Total	6
Eighth Semester (15 Hours Required.)		
NEW- TECH 4	Sustainable \Senior Project	3
NEW -TECH 3	Energy Storage and Conversion	3
NEW- TECH 4	Emerging Green Technologies	3
H or SS Elective	Humanities or Soc. Sc. Elective	3
R386	Ethics of Consumption	3
	Total	15
	Total Credit Hours	**122**
Technical Electives		
MET	Co-generation and CHP systems	3
EECT	Wind, Photovoltaic, Wave	3
EECT	Solar, Geothermal.	3
EECT	Biofuels, Hydrogen	3
AT,CEMT	Sustainable Community Design	3
CIMT	Sustainable IT	3
Environ Science	Sustainable Ecosystems	3
SPEA	Greening Healthcare	3

For the 2009-10, Indiana University-Purdue University Indianapolis (IUPUI) will kick off a campus wide common theme project. The book chosen for the common theme is, *Deep Economy*, by Bill McKibben. The theme of "sustainability" will be launched in September 2009 for two years on the IUPUI campus and the surrounding community. Committees have been planning all year for monthly events related to the theme for the next academic year. There is a golden opportunity for the faculty working on the BS in Sustainability degree to promote and encourage students and potential students about the program. As well, this is an excellent opportunity for that same faculty to duplicate the example at Missouri State University (Springfield) and hold workshops for faculty on sustainability during this same period.

VII. FUTURE TRENDS TOWARDS GREEN JOBS

A report on future Green Jobs was commissioned by the United Nations Environment Program in conjunction with the International Labour Organization, International Organization of Employers and International Trade Union Confederation. The 352 page report is titled, Green Jobs: Towards decent work in a sustainable, low-carbon world. For purposes of this paper an the report, green jobs are defined as those that contribute substantially to preserving or restoring environmental quality and in the areas agriculture, manufacturing, research and development, administrative, and service activities that contribute to preserving or restoring environmental quality. Green jobs would also include jobs that protect the ecosystems and biodiversity; reduce energy,

materials, and water consumption through high efficiency strategies; de-carbonize the economy; and minimize or eliminate waste and pollution. [12]

Green jobs are rapidly being created as the economy begins embracing sustainable and low-carbon practices. The driving forces behind the development of green jobs are businesses wishing to maintain cutting edge technology while lowering their carbon foot print or becoming entirely carbon neutral. The governments of the world support these developments through initiatives including: subsidies, tax reform, and carbon markets.

The authors of the Green Jobs Report found that the global work force supports 300,000 workers in wind technology and approximately 170,000 in solar photovoltaic (PV). More than 600,000 workers are employed in solar thermal development and approximately 1.2 million are employed in developing biomass technology. Considering the increase of interest in alternative energy, the future may see worldwide employment soar as high as 2.1 million in wind technology and 6.3 million in solar PVs by 2030, and somewhere in the area of 12 million jobs in biofuel related agriculture and industry. Estimates indicate strong potential for large job creation in coming years. Installation and maintenance of solar PV and thermal systems in particular offer the most growth. [12]

The report indicates that a leading barrier to renewable energy and energy efficiency growth in the U.S. is the shortage of skills and training as noted by the U.S. National Renewable Energy Laboratory. This was also the case in Germany and Britain. These shortages will continue to drive demand for educated workers in the new green economy, placing the burden of educating and producing skilled workers on the world's universities. The level of education necessary to be proficient in green technology requires universities wishing to service their communities to expand existing degree programs or possibly create new ones. In order to provide employees for these green jobs, engineering and technology schools need to respond with new courses and programs that will fit industry's need for this green change. All levels of engineering and technology education will be needed in this new green environment. Almost every industry imaginable will be touched by sustainability trend.

Even in the State of Indiana, a state that ranks near the bottom in wind energy usage, there is an 87 wind turbine farm located in the northwestern section of the state near the town of Earl Park. Who will install and maintain the turbines? Community colleges have been the first to respond to the call for green jobs in alternative energy. Highland Community College in Freeport, Illinois announced their program in alternative energy. The school is completing details to offer a cooperative wind turbine program, which includes an Associate Science degree. Perhaps these graduates will fulfill the needs in Earl Park, Indiana. [13]

VIII. CONCLUSION

The theme for the World Engineering Convention, held in Brazil December 2008, was "Engineering Innovation with Social Responsibility." Over 5,500 engineers from around the world attended the meeting. The Key Note Speaker, Hans J. Hoyer, representing the International Federation of Engineering Education Societies (IFEES) addressed the audience on "Global Competence and Mobility in Engineering Education." His talk was about the challenges and obstacles faced by globalizing engineering preparation and examples of recent organizational developments to create socially responsible networks of engineering. Social responsibility includes the knowledge of sustainability. [8]

It is the responsibility of engineering and technology faculty to remain current in their discipline, which includes the new knowledge of sustainability and how it relates to their discipline. Faculty should be able to bring this knowledge to their teaching, research and service. Engineering and technology students must to be ready to face global challenges today and tomorrow. They must understand how to work and solve problems in a global world. Are you prepared to teach your students how to solve global challenges in a sustainable way?

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