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Enabling Construction Engineering Students in Sustainable Thinking: Curricular Changes to Foster Sustainability

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ABSTRACT

Globalization has captivated and heightened our awareness of the importance of ecological integrity and diversity. Earth-friendly, sustainable building design and construction practices are no longer a mere fad, but have become an urgent necessity. Modern construction engineers should be educated on sustainability and equipped with critical reasoning so that they can avoid the same mistakes as their less-than-green predecessors.

This paper addresses the need for curricular changes to foster sustainable thinking. Also, the implementation of a course in the Texas Tech University Construction Engineering Technology program is discussed.

Keywords: Sustainable Education, Engineering Curricular Changes

INTRODUCTION

Over the last three decades, global attention has focused on the concept of sustainability, and sustainable development has been introduced to address and overcome causes and effects of human activities' increasing negative impacts on environment. Parallel to the global trend In the U.S.A., there is an increasing demand, in both the public and private sectors, to understand sustainable design and construction practices. This demand is driven by the realization of the need for sustainable practices that not only help the environment but that can also improve economic profitability and improve relationships among many stakeholder groups (Darwish, et al., 2009).

Many colleges of engineering have added sustainable design and construction to their curricula. But for the most part, progress has been in the private sector, led by the U.S. Green Building Council, innovative building material suppliers, and passionate individuals. Such interest has allowed progress to be made so that the private sector has moved ahead of academia (Bowers, 2006; Business Leader, 2007; Hallford, 2007; Northcott, 2007; Northcott and Richter, 2007; Vanderhoff, 2007). Also the need for innovation in teaching engineering has been noted in both educational and industrial sectors to close the gap that too often has existed between industry and the academy for years (Cooper, C. 2000; Grasso et al., 2003; Mc Masters and Ford, 1990;Salamon and Engel, 2000.) Progressive engineering educators and industry leaders emphasize that engineering students must be equipped with critical and creative thinking skills to ensure the American industry will have continued success (Felder and Brett, 2004). Educators in construction engineering and management programs must encounter these important points and implement methods to enhance students' critical and creative thinking skills and to foster sustainability in their teaching. Education relevant to the challenge of building a sustainable society will enhance learners' competence with natural systems. Practical competence is not only an indispensable source of good thinking, but will be required to face the sustainability challenges of food, energy, water, and material shortages. The *sustainability concept*, therefore should be implemented in engineering curricula so that future construction engineers will be educated in sustainability and equipped with critical reasoning so that they can avoid the same mistakes that their less-than-green predecessors have made and so that development can occur sustainably. Green development is

the way to protect jobs and the environment. In fact, unless we promote green development, we cannot sustain a quality of life; unless we preserve the environment, we will not have jobs in the future.

Changing Direction to Sustainable Construction

The sustainable development movement was started after the establishment of "Earth Day", at which point scientists and educators began talking about air and water pollution, toxic chemicals, and hazardous waste (Orr, 1992). The thought was that solutions to those problems are known. Government regulations would limit pollution and require enterprises to use the best available technology to reduce it, thus including the costs in the price of goods. The more we learned, the more we regulated. Twenty-nine years later, progress made it this effort to address air and water may not be as efficient that it should be, but at least things are not much worse than in the 1970's. However, we have lost momentum in correcting wrong doings or finding solutions to the environmental crises created by modern life, production, agriculture, and construction. Still acid rain falls into the rivers, and stratospheric ozone has depleted, in turn, increasing the planet's exposure to ultraviolet rays. The loss of biodiversity is accelerated as we see the decline or extinction of many bird, bees, fish and insects. Much of the Earth is facing shortages of water, oil or both. Human activities are altering its basic chemistry and biology on a very large scale and at an increasing rate.

According to the United Nations, there are 6.7 million humans on earth and the number is expected to rise. From the time that measurement began, the level of carbon took its largest jumped at three parts per million in 2006 (Kibert, 2008). Human and environmental health are severely affected by pollution and weather extremes driven by climate change. In fact, buildings, infrastructure and the environment are inextricably associated. Energy, materials, water, and land are consumed in the construction, operation, and maintaining of buildings and infrastructure. Energy, materials, water and land are all consumed in construction operations. Buildings draw one-sixth of the world's fresh water, use one-quarter of wood harvest, and expend two-fifths of its material and energy flows (Gottfried, D. 2005). A global estimation by Davoudi and Layare (2001) asserts that 70 % of all timber is used for buildings; 45% of energy generated is to power and maintain buildings, and 5 % to construct them. Structures also impact areas beyond their immediate location, affecting watersheds, air quality, and transportation patterns of communities (Rodman and Lenssen, 1996).

To approach finding solutions to the ecological problem as it has been in the past, technological fixes and single solutions for single problems have been tried. Such efforts do not do enough. Instead, what is required is a fundamental change in the way we meet our needs and a reassessment of what those needs really are.

The challenge of 21st century requires that we make a transition to a new order of things that can be sustained; perhaps, the most important transitions must be in the building/construction sector. The concept of sustainability in building and construction must focus not only on limited resources, especially energy, and on how to reduce impacts on the natural environment, but also on technical issues, building components, materials, construction technologies, and energy-related design concepts.

Defining Sustainability and Sustainable Construction

Sustainability, as defined in the Brundtland Report of 1987 (also known as *Our Common Future*), as development "that meets the needs of the present without compromising the ability of future generations to meet their own needs." This report was significant because it led to actions, including UN Earth Summits (in Rio de Janeiro in 1992 and in Johannesburg in 2002), International Climate Change Convention, "Agenda 21" Programs, and the creation of international sustainable development strategies.

Sustainable development is comprised of the three broad themes of social, environmental, and economic accountability, often known as the 'triple bottom line' (Parkin, S., 2000). As shown in Figure 1 and Figure 2, sustainability is the interaction and connection between society, the environment, and economic/industrial development.

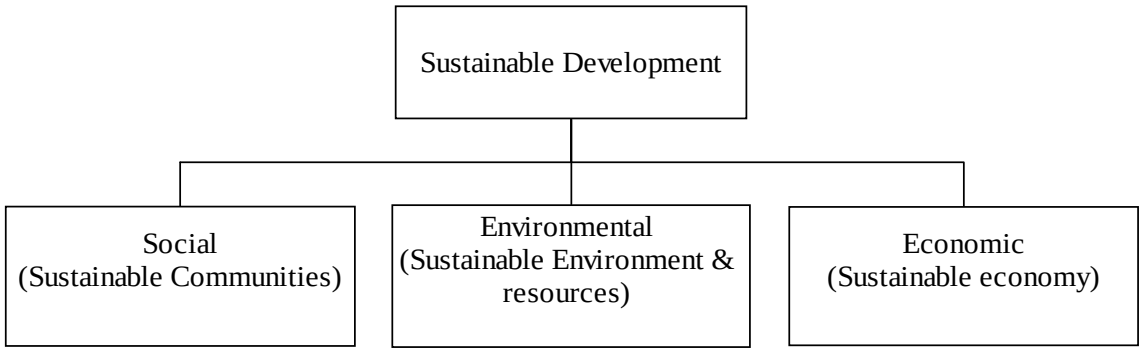

Figure1. Three basic concepts of sustainability

Parallel to the sustainable development concept, sustainable construction may be defined as application of sustainable practices into construction industry, including design and construction. In figure 1, interaction of three basic concepts of sustainability is presented. Sustainable building is a rapidly growing practice in new construction development in the U.S.A, as the green development movement has been adopted by engineers, designers and builders. Life-cycle analysis shows evidence that sustainable design and building make good economical sense and have environmental impact. It is expected that this trend continues with an accelerating speed, with 99% federal and state buildings expected to be built for sustainability, and raised standards of existing buildings to include green renovation that will bring them up to a sustainable state.

As emphasized here, in order to achieve sustainable development, in general, among both industrialized and developing countries, the interrelationship of social, environmental and economic aspects of the built environment must be realized. However, without an adequate understanding of how societal and industrial actions impact the environment in which we live or how today's activities may impact the future, tomorrow's builders and construction engineers are in the dark. In order for future construction engineers and technologist to participate in sustainable development, they will be required to evaluate and apply information from multiple disciplines including economics, social and environmental sciences, and they also must be educated in ecological literacy. They should be equipped with the up-to-date knowledge and skills to be able to manage any uncertainties that may arise and make judgments on the available evidence in built environmental design and construction. These knowledge bases require engineering colleges to implement sustainable development and construction courses in the curriculum so that students will be educated and equipped with the required knowledge and creative and critical thinking skills.

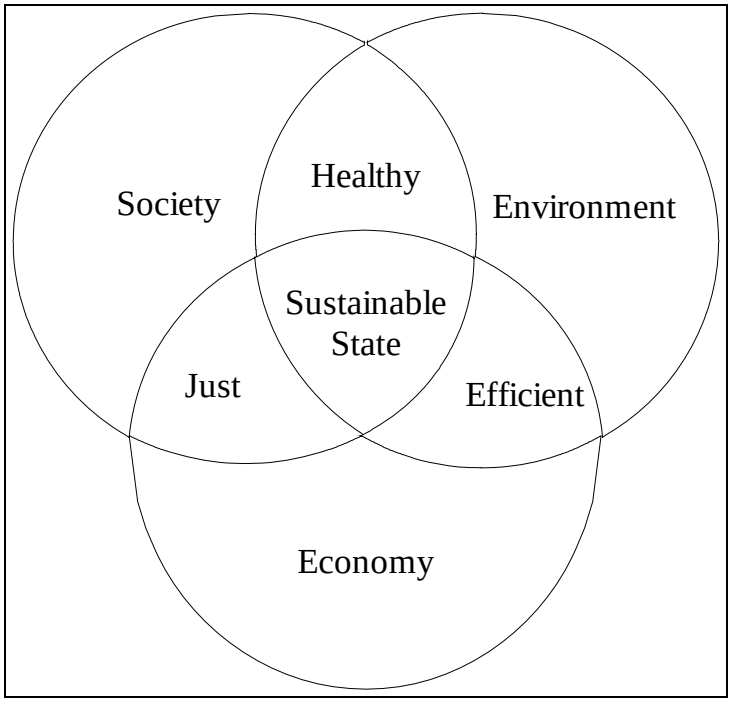

Figure 2. Interaction of three basic pillars of sustainability concepts.

Integration of Sustainability Principles and Methods into Engineering Curricula

Wise at al., (2004) after conducting a four-year longitudinal study of the intellectual development of undergraduate engineering students, concluded that students need active learning and team-based projects in order to progress adequately in the terms of intellectual growth and successful integration of sustainability principles and methods into engineering curricula requires a systemic change in our approach to education and societal values. Students not only need the knowledge base to make sound engineering decisions, they also need the intellectual development to supply effective solutions to complex technical problems.

Integration of sustainability into engineering curricula requires commitment of educators to facilitate intellectual development of students. King's (2000) research resulted with findings that intellectual development can promote social and cultural awareness among individuals and supports sustainable thinking; furthermore, by developing critical thinking in engineering students, the next generation of professionals may be more likely to give consideration to issues related to social equity, biodiversity, and the environment. Two approaches may be employed to incorporate sustainability perspectives into engineering curricula such as the center approach or the whole curricula approach. The Center approach requires more resources and more commitment from administration. The whole curricula approach can be employed by designing new curricula which will integrate more sustainable-green perspectives, cultivating sensitivity to the environmental, biodiversity and sustainability issues in students in all engineering disciplines.

Teaching sustainability to construction engineering technology students may be possible by employing interdisciplinary study and a whole curricula approach. Such movement away from isolated discipline study is requisite because the construction industry is complex and there are myriad professions such as architects, engineers, and construction managers etc., who are involved in the procedure of decision making. Therefore, the design and building of sustainable buildings require working closely with interdisciplinary teams. The Texas Tech program integrated sustainability into curricula with the consideration of an interdisciplinary vision of the construction industry in need of development.

The "*Introduction to Green Development and Construction* course" at the undergraduate and graduate level offered in spring 2009, is the first course in the College of Engineering at Texas Tech University to be offered to educate students in sustainable development and green construction principles. Topics covered in this course include:

1. Introduction to sustainable/green development
2. Green building resources and references
3. Advancing Green building technologies and innovations
4. Impacts of building construction, operation and disposal
5. Green building assessment and process
6. Sustainable construction materials
7. Ecological design
8. Review for LEED-AP exam
9. Introduction to LEED
10. LEED design process

a. Filling the LEED credit templates
b. Site design
c. Water management
d. Energy use optimization
e. Energy and atmosphere
f. Construction materials sources

Students enrolled in this course are doing multidisciplinary study including construction engineering technology, architecture, civil engineering, interior design, mechanical engineering; additionally, throughout the semester they work in teams as it in real world situations. Teaching promotes student-centered learning. Students are also allowed the chance to implement what they have learned through the building of a sustainable activity center in Crosbyton County for the local Girl Scouts of the area. This helps in solidifying the principles the students are taught as well as allows them the opportunity to gain new experience to help with their novice status in sustainable building applications. The Accreditation Board for Engineering and Technology (ABET) is charged with the task of` "quality assurance in higher education" for programs in applied science, computing, engineering, and technology. Of particular interest are ABET's requirements for program outcomes and assessment, which identify the knowledge, skills, and behaviors students should have when they graduate from an engineering program (ABETT 2005-2006 criteria). Our approach responds to ABET's criteria with training our students in (1) functioning on multidisciplinary teams,(2) communicating effectively, and (3) understanding professional and ethical responsibility. Related ABET criteria include (a) designing a system component or process, (h) understanding global, economic, environmental, and societal contexts, and (i) major retention.

Conclusion:

As the population of the world increases, there is now a larger demand for resources and energy than in the past few decades, which in turn creates a rise in pollution. The world is fast approaching or may be exceeding the earth's limits for sustaining human life leading to unavoidable tradeoffs between the number of people than can be supported and the material level at which each person can be supported.

Today educators are facing a great challenge to educate future post/modern engineers on sustainability and equip them with critical reasoning so that they can avoid the same mistakes made by their less-than-green predecessors.

Successful integration of sustainability into engineering curricula demands a change in the approach to education. Students need not only the knowledge base to generate effective engineering solutions, they also need the intellectual development and environmental awareness to understand the impact of their decisions. Learner-centered environments steeped in ecological literacy are a prerequisite to the redesign of engineering education integrating sustainability into the curricula.

REFERENCES

Accreditation Board of Engineering and Technology, Criteria for Accrediting Engineering Programs: Effective for Evaluations during the 2005±2006 Accreditation Cycle (2004).

Bowers, C.A. (2006). Revitalizing the commons: Cultural and educational sites of resistance and affirmation. NY: Lexington Books.

Cooper, C.(200) "Product Innovation and Technology Strategy." Research /Technology Management, Vol. 43, No. 1, 38-41.

Darwish Muge Mukaddes. Agnello Maryfrances, Buelinckx, Hendrika (2009) Why Sustainable Construction Why Now? 'Fifth International Conference on Construction in the 21st Istanbul Turkey.

Felder R.M.and R. Brent, (2004) The intellectual development of science and engineering students.Part 2: Teaching to promote growth, Journal of Engineering Education, 93(4) (2004b), pp. 269±277.

Grasso, D. M Callahan and S. Doucett,(2003) Defining engineering thought, International Journal of Engineering Education, 20(3) pp. 412±415.

Hallford, A. (November, 2007). Fort Worth adds some color to the greening of America: Going green in cowtown. Fort Worth's Good Nature.

J. R. Mihelcic, J. C. Crittenden, M. J. Small, D. R. Shonnard, D. R. Hokanson, Q. Zhang, H.Chen, S. A. Sorby, V. U. James, J. W. Sutherland and J. L. Schnoor, (2003) Sustainability science and engineering: The emergence of a new metadiscipline, Environmental Science and Technology, 37(23), pp. 5314±5324.

King,P.M, (2000) Learning to make reflective judgments, in M. B. Baxter Magolda (ed.), Teaching to Promote Intellectual and Personal Maturity: Incorporating Students' Worldviews and Identities into the Learning Process, New Directions for Teaching and Learning, No. 82, Jossey-Bass, San Francisco.

McMasters, J. and S. Ford. "An Industry View of Enhancing Design Education." Journal of Engineering Education, Vol. No. 79, No. 3, 1990, 526-529.

Michael Montoya, (2009). *Green Building Fundamentals*. Prentice Hall.

Northcott, K. (November, 2007). Energy reality check: Green power for Texans and their co-ops. Texas Co-Op Power, 6-13.

Northcott, K. and Ricther, R. (October, 2007). Energy reality check. Texas Co-Op Power, 6-14.

Orr, D. W. (1992). Ecological literacy. Education and the transition to a postmodern world. Albany: State University of New York Press.

Parkin, S. (2000), Context and drivers for operationalizing sustainable development, Proceedings of ICE, Vol. 138, Nov. 2000, pp. 9 – 15.

Preston Koerner's report on http://www.jetsongreen.com/2009/01/president-obama-impact-on-green-buildings.html (retrieved on 2/14/2009).

Salamon, N. and R.S. Engel.(2000) "A Management/Grading System for Teaching Design in Mechanics of Materials and Other Courses." International Journal of Engineering Education, Vol. 16, No. 5, 189-196.

Splitt,F.G,(2003)Systemic engineering education reform: A grand challenge, in The Bent of Tau Beta Pi, pp. 29±34.

United Nations, Rio Declaration on Environment and Development, The United Nations Conference on Environment and Development (UNESCO), Rio de Janerio, Brazil (1992).

Wise, J.C, S. H. Lee, T. Litzinger, R. M. Marra and B. Palmer, A report on a four-year longitudinal study of intellectual development of engineering undergraduates, Journal of Adult Development, 11(2) (2004).

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