AC 2009-1794: SUSTAINABILITY OR GREEN: CHALLENGES AND CHANGES FOR EDUCATORS AND THE ENGINEERING CURRICULUM

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Sustainability/GREEN: Challenges and Changes for Educators and the Engineering Curriculum.

Abstract:
Education for sustainability in general is a process that develops students' awareness, competence, attitudes and values, enabling them to be effectively involved in sustainable development at local, national and international levels, and helping them to work towards a more equitable and sustainable future. In particular, it enables students to integrate environmental considerations into economic decision-making. As a result it is imperative that academics in engineering, construction, education, and other disciplines heed the call for sustainable technologies, policies, and practices. Although since the early 1990's many environmental and professional organizations such as the American Institute of Architects (AIA) and accrediting agencies such as the American Council for Construction Education (ACCE) and the National Architectural Accreditation Board (NAAB) have appealed to universities to provide education for sustainable development and encouraging students to be involved with matters of the environment, the curricula in many universities sparingly offer classes which provide information and current understanding of sustainable development.

While professional agencies and organizations have taken lead roles in embracing the emerging sustainable trend, universities are still slow to include sustainable development in their curricula. In all probability this gap will steadily grow if universities do not embrace a concerted interdisciplinary effort to change their curricula and take the challenge to change engineering education to include sustainable development in their curricula. Today's students, as tomorrow's engineers are the people who are going to build future communities; thus it is imperative that they have an understanding of the impacts of their decisions on the environment and natural resources to allow such positive changes to occur.

This paper will examine to the challenges posed by introducing sustainability into engineering. It offers a model of K-12 curricular changes to include sustainable/GREEN development into the existing curriculum in Engineering and related discipline programs.

Key words: Sustainability, Education, Collaboration, interdisciplinary curricula, green curriculum development

Introduction:

'Education for Sustainable Development is an investment in our future… each respective country should ensure that appropriate resources are made available for its development' - World Summit on Sustainable Development: Plan of Implementation (2002).

As time progresses the world seemingly begins to unravel due to the deliberate negligence of an ignorant populous. This neglect is leading to an environment in which change can be volatile to mankind's secure existence. Is it possible to solidify man's grasp of sustaining its livelihood? The World Commission on Environment and Development (Brundtland report) concluded 23 years ago that, "humanity has the ability to make development sustainable". The Brundtland report defined *sustainable development* as the "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987). Therein the emphasis lies on not compromising the future through sustainable development methods that reflect positively on current situational needs with a lasting appeal towards the future.

David W. Orr (1992) widened the scope of sustainability in his seminal book "Ecological Literacy" from technological to ecological sustainability. Technological sustainability mainly deals with technological and ethical issues; ecological sustainability is considered an effort that affects all aspects of a culture. In order to adequately prepare us for the future, Orr envisions a dramatic shift in the existing pedagogies of all educational programs—a shift toward an earth-centered education. Earth-centered education entails a rethinking of both the theory and methods of education at all levels. Education informed by sustainability, ecological literacy, and green building principles also entails a renewal of the ways in which we teach engineering.

Chet Bowers (2005) argued that educating students in environment issues and on environmental literacy will empower them to find solutions to environmental problems arising from past actions. Therefore ecological literacy is crucial in engineering education. When we introduce environmental teaching into engineering, it should not be approached in a purely scientific perspective, but also ethics should be addressed as they are identified in McKeown-and Dendinger (2000). Scientific knowledge and political interventions alone are not able to solve the environmental problems; therefore attitude change is required, and this can be achieved through education. Orr (1992) maintains that ecological literacy can play a key role by creating environmental awareness and changing peoples' values, skills and behavior.

Thus the term education for sustainability or sustainable education complements a number of fields such as environmental education, multicultural education, conservation education, global change education, ecological literacy education, sustainable engineering in broad terms. Education for sustainability in general is a process that develops student awareness, competence, attitudes and values, enabling them to be effectively involved in sustainable development at local, national and international levels, and helping them to work towards a more equitable and sustainable future. In particular, it enables students to integrate environmental considerations into economic decision-making. As a result it is imperative that academics in engineering, construction, education, and other disciplines heed the call for sustainable technologies, policies, and practices.

Change is good

As societies need to change so do their educational systems. The curriculum is a most logical place to begin educating about the importance of sustainable construction. In social studies, a study of the places where and in which people from around the world live is standard pedagogy. Re-introducing traditional peoples' methods of construction puts students in touch with buildings as part of the natural environment. At every level of science, mathematics, social studies, language arts, technology, and arts classes, human abodes and constructed places are relevant topics to study. Comparing civilizations' architectures and usages of natural resources can be done through interdisciplinary studies that touch on all of the subjects. The global complexity of sustainability is often approached with children through the study of the rain forest. The rain forest study can become more complex as students progress. Ethnobotany, or the use of plants for healing and sustenance by various groups of people, can lead to chemistry discussions of pharmaceuticals that come from plants that originate in the rain forest. Related to such study is the study of the places where people live in such settings. Eco-friendly *ethnoconstruction* would take into account Orr's (1992) environmental literacy and combine with it a study of the built sustainable environment. It is not a study that should be relegated only to future architects and engineers, who are usually particularly gifted in the study of mathematics and science, but it should be studied by all people who will live in constructed abodes.

Research of various tribes around the world is done by sociologists and anthropologists. Their bodies of work contain information about construction and the built environment. By connecting the built environment to the study of science, mathematics, arts, social studies, and language arts, all students gain a sense of wonder about human progress but also come to appreciate that all progress is not positive. Mothership earth has a finite supply of resources for all of living organisms' needs. When youngsters and adolescents become familiar with the dilemmas of unsustainable construction currently in use, they can compare, contrast, envision, articulate, persuade, offer service, and enact values taught to them in the curriculum to join the family of global citizens who will be obligated to take better care of and utilize fewer resources than they would otherwise. American citizens cannot continue to ignore that a minority of the population in the Northern hemisphere and United States uses the greatest percentage of the world's resources. If we do not learn to share more equitably what is here to use, we not only are living in denial, but more importantly, subject ourselves to greater chances of invasion and attacks from the outside. Unfortunately, social change is usually difficult and slow. We have reached a point in history where sustainability is not only a desirable goal of education, but rather is a requisite that should be on the forefront of curriculum development and educators' minds. Eco-friendly approaches to construction and in general, engineering, are the purview of all global citizens and it is through K-12 education that the need and vision for doing such construction will be taught and learned.

Challenges and barriers education for sustainability:

While world sustainability is a global trend that has captured worldwide attention, in 2002, the United Nations General Assembly adopted Resolution 57/254 to designate the decade 2005-2015 as the 'United Nations Decade of Education for Sustainable Development' (UN-DESD web site retrieved 12/13/2008). GDRC, the Global Development Research Center, endorses and supports global initiatives to activate the decade of 2005 - 2015 as the 'UN Decade of Education for

Sustainable Development' (GDRC, web site retrieved 1/10/2008), only limited progress has been made on any level of education.

Since the early 1990's many environmental and professional organizations such as the American Institute of Architects (AIA) and accrediting agencies such as the American Council for Construction Education (ACCE) and the National Architectural Accreditation Board (NAAB) have appealed to universities to provide education for sustainable development and encouraged students to be involved with matters of the environment. On the contrary curricula in many universities sparingly offer classes which provide information and current understanding of sustainable development. (Darwish et., 2009)

Tallories, Halifex, The Swansea and Copernicus declarations expressed that sustainability can only be achieved either by specialists from sustainability programs or from sub-disciplines, with sustainability concepts and practices incorporated into the mix of a discipline's courses as appropriate. Certainly, many courses are discussing sustainability or environmental issues as pressing topics; however, this is done primarily on an ad hoc basis and with little reference to the theories and practices of sustainability science. The critical factor is likely the lack of knowledge, time or incentives on the part of instructors to build these concepts into their course materials. There is also an indifference or marginalization of environmental concerns in dominant textbooks. And existing engineering curricula are limited with prescribed credit hours and no place to add more courses. For example Construction Engineering Technology curricula at !!!! University (????) are fixed to 126 credit hours, and administrators resist adding any more courses. While introduction to "new ideas" has always raised difficult debates among specialists in education, academic staff can also be ideologically resistant to curriculum changes. Sustainable development in engineering is a relatively new concept in and developing new courses demands extensive preparation which puts pressure on faculty.

Around the world, increasingly, these barriers are being overcome by the use of approaches such as prepared case studies and field-based case studies (Steiner and Laws 2006), modules developed for specific disciplines (Paten and Palousis, 2005), and trans-disciplinary team teaching (Caviglia-Harris,2004 and Filho, Walter L.,2002).). These approaches incorporate sustainability theory and practice and teach students to work in a trans-disciplinary perspective.

Although institutions of higher learning have been urged to become more innovative and responsive to a globally competitive knowledge market, and ABETT requires students are "industry-ready", unfortunately engineering schools in the U.S.A have been slow to follow the worldwide sustainable education trend.

Preparing for a change and a frame work for a sustainable curriculum

Calls for reorienting education to address sustainable development as seen in Chapter 36 of *Agenda 21*, reorient engineering education to implement suitable courses and may require re-allocation of resources. However, if the implementation is done wisely and incorporation of interdisciplinary and transdisciplinary courses achieve education about sustainability, obsolete resource allocations can be averted,-- which in the short and long run, will contribute to reorient education to address sustainability.

Two approaches may be employed to incorporate sustainability perspectives into engineering curricula as:

1) Center approach
2) Whole curriculum approach

Center Approach:

A multidisciplinary GREEN center may be developed which will serve to:

- Open new fields of study and future research and development while increasing and diversifying student population
- Provide focal points for the increasing environmental awareness
- Coordinate GREEN engineering research projects that engineering professors and students from cross engineering and other related disciplines pursued independently in the past
- Provide GREEN perspectives for an interdisciplinary approach to students from a variety of disciplines
- Facilitate and advocate for sustainability issues in Engineering Colleges, through the university and the society at large
- Develop innovative interdisciplinary courses which can be taught through multi-discipline faculty

(The Georgia Institute of Technology's Center for Sustainable Technology is an exemplary model to this approach.)

Whole curriculum approach:

The new curriculum may be designed integrating more sustainable-green perspectives, cultivating sensitivity to sustainability issues in students in all engineering disciplines. Such curricula include government-industry collaborations and assessment activities in green engineering. Curricula must include courses that promote and teach GREEN design principles and environmental awareness, ecological literacy, environmental economics and sustainable ethics. Ideally, organization would establish accountability and methods of programmatic evaluation of the curricula to determine if indeed the objectives of sustainability had been mastered by students.

Implementing Interdisciplinary Approach in Sustainable Construction in Construction Engineering Technology in TTU

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. As it is argued in Jucker (2002), we need to overcome the disciplinary confinement of current education, that makes implementing sustainability in the built education difficult, and that prevents each educator from looking beyond one's own narrow field of vision. Teaching sustainability fosters civic responsibility and develops informed citizens who are responsible to their professions, communities, posterity and the world.

A new course was developed by Dr. Darwish focuses on theoretical and practical applications that utilize and implement Green construction practices. An *Introduction to Green Development and Construction* course, at the undergraduate and graduate level offered in spring 2009, which was the first course in the College of Engineering in Texas Tech university to be offered to educate students in sustainable development and green construction principles and thought as an interdisciplinary approach to engineering, architecture, and construction management. Using an interdisciplinary approach to teach is a very positive manner in which to teach construction courses and introduce sustainability practices to students.

The benefits of teamwork on a common project allow students to flourish and gain experience that will better meet the needs of the construction industry. Throughout the semester guest lecturers and speakers are invited to give new insight to the students on GREEN building and the LEED rating system. Practicing architects provide students GREEN design principles while the professor educates the students in the area of the LEED AP accreditation exam. 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 application.

Topics covered in this course are:

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

Sustainability in K-12 Education—a logical starting point

In table1, the authors propose a model for K-12 Curricula that includes attention to sustainability. The concepts of green engineering are present in the early grades of the social studies but are not

expanded in meaningful ways that tie to the sciences, economics, government, and arts which might seem a logical starting point for future green designers and engineers. Here below is a suggested green curriculum that can be taught in every grade in science, mathematics, language arts, social studies, technology and the arts. This curriculum builds on skills required by the Texas Essential Knowledge Skills in the four major disciplines (science, mathematics, language arts, and social studies), technology, and the arts. Transformative education is a philosophical and instructional approach to education that helps students make connections between their disciplines, their learning, and their lives in a ecological system. They begin to see how the sciences are interrelated with engineering, and design that altogether give them a vision of their lives in a system and the need for them to move beyond wasteful and self-oriented practices to life skills that take into consideration the world and its limited resources.

Table. 1 Building Green Curricula in Grades K-12

Disciplines **K-12**	**Sustainable** **Engineering**	**Unsustainable** **Engineering**	**Transformative Education**
Science	Scientific method Life cycles Environment/s Interconnection of systems	Scientific method Life cycles Environment/s Intersection of many disparate systems	Students envision the possible and articulate the steps needed to go from unsustainable construction to sustainable construction in bio and geo scientific study, projects, and community work
Math	Measurement Ratios Comparisons Algebraic and other functions that describe sustainable buildings	Measurement Ratios Comparisons Algebraic and other math functions that describe traditional buildings	Students perform mathematical operations in word problems that represent the uses of water, construction materials, etc. in a finite system; they calculate the needed changes to conserve resources and preserve various eco-systems
Language Arts	Read, write, research listen to non-fiction that interweaves the	Traditional curricular practices in	Students embrace the language of possibility through interdisciplinary

	other disciplines into environmental dilemma, globalization problematic, and need for green construction	literary, semantic, and rhetorical study	studies of specific green construction case studies; persuasive speech, and other linguistic practices
Social Studies	Geographic, historical, economical treatment of place/s with respect to greening the environment	Geographic, historical, economical agriculture, construction, economy, etc. that are unsustainable	Students engage in community service and eco-economics study to connect tangible local resources to sustainable communities on a global scale
Technology	Engagement in hands-on activities and digital computer study of habitats	Study of traditional technology history and rationales	Innovate with technologies to ascertain their utility for sustainability; re-design modes of production; recycle construction and other materials
Arts	Aesthetics, drawing, design of innovative green buildings	History of construction and architecture	Design green construction for health, economy, engaged citizenship

Conclusion:

Today, despite of the barriers and difficulties, educators are facing a great responsibility to educate society by fostering the transformations needed to set us on the path to sustainable development. The common theme that runs through these agreements is that universities must actively develop the programs and faculty capacities that will produce students with a high level of environmental literacy and the ability to deal with environmental issues on a disciplinary, interdisciplinary and transdisciplinary basis. This multi-pronged approach provides an understanding of the main environmental issues, how sustainable development meets the environmental challenge with a systemic approach, and the tools to put sustainability into practice. If we do not respond to this challenge we will be failing our students and our community. Moreover, we will fall behind our peers in other parts of the world who are racing forward in commitment, action and innovation.

Related terms:

Agenda 21 is a program run by the (UN) related to sustainable development. It is a comprehensive blueprint of action to be taken globally, nationally and locally by organizations of the UN, governments, and major groups in every area in which humans impact on the B. The number 21 refers to the 21st century.(United Nation Sustainable development)

GDRC: The Global Development Research Center

LEED Certification: "LEED Certification distinguishes building projects that have demonstrated a commitment to sustainability by meeting the highest performance standards." (USGBC LEED Certification website, retrieved 12/21/2008).

Sustainability: in a broad sense, is the capacity to maintain a certain process or state. It is now most frequently used in connection with biological and human systems. In an ecological context, sustainability can be defined as the ability of an ecosystem to maintain ecological processes, functions, biodiversity and productivity into the future.(*Our Common Future, 1987)*

Sustainable/ Green Engineering: Green engineering is the development and commercialization of economically feasible industrial processes that reduce the risk to human health and the environment.

Talloires Declaration: In October 1990 twenty university presidents, rectors and vice chancellors of universities from all regions of the world publicized their concerns about the unprecedented scale and speed of environmental pollution and degradation, and the depletion of natural resources. These environmental changes they said threaten the survival of humans and thousands of other living species, the integrity of the earth and its biodiversity, the security of nations, and the heritage of future generations. The Talloires Declaration, as it is called from the Tufts University European campus in Talloires, France, and then stated in the simplest and starkest of terms: We believe that urgent actions are needed to address these fundamental problems and reverse the trends. [D. Johnston] (http://www.iisd.org/educate/declare.htm#tal revised 11/13/2008)

The Halifax Declaration: in December 1991 at Halifax (Canada)... senior representatives of the IAU, the United Nations University, and the Association of Universities and Colleges of Canada joined by 20 university presidents from various parts of the world, eg, Brazil, Indonesia, Zimbabwe added their voice. The Halifax Declaration expressed dismay about the continuing widespread degradation of the earth's environment and the pervasive influence of poverty on the process, and about the unsustainable environmental practices now so widespread. [D. Johnston] (http://www.iisd.org/educate/declare.htm#tal revised 11/13/2008)

ACU -- The Swansea Declaration In August 1993 at the conclusion of the Association of Commonwealth Universities Fifteenth Quinquennial Conference in Swansea, Wales, the increasing sense of urgency among university leaders broke through the barriers of competing claims for concern. Participants drawn from over 400 universities in 47 different countries focused on the topic of People and the Environment -- Preserving the Balance. Their quest? To find ways by which the universities of the Association of Commonwealth Universities, their

leaders, scholars and students might engage and deploy their unique common traditions ... to respond appropriately to this challenge. [D. Johnston] (http://www.iisd.org/educate/declare.htm#tal revised 11/13/2008)

The Kyoto Declaration**:** in November 1993 the IAU in its 8th Round Table meeting in Japan issued a clarion call to its 650 university members in the Kyoto Declaration. [D. Johnston] (http://www.iisd.org/educate/declare.htm#tal revised 11/13/2008)

CRE Copernicus Charter: the University Charter for Sustainable Development is an instrument created by Copernicus, an inter-university co-operation programme on the environment, established by the Association of European Universities (CRE). The Charter expresses a collective commitment on behalf of a large number of universities. It represents an effort to mobilize the resources of institutions of higher education to further concept and objective or sustainable development. The Charter was introduced and presented to the CRE bi-annual conference in Barcelona, in the autumn of 1993. Two years later, the document has been endorsed by the personal signature of the rectors of no less than 213 universities in Europe. (http://www.iisd.org/educate/declare.htm#tal revised 11/13/2008)

UN DESD: United Nations Decade of Education for Sustainable development.

USGBC: United States Green Builders Council

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