for better
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ideas

Engineering Education for Sustainable Development

Number 19
March 2016

Committee on Education In Engineering
World Federation of Engineering organizations

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WORLD FEDERATION OF ENGINEERING ORGANIZATIONS

FÉDÉRATION MONDIALE DES ORGANISATIONS D'INGÉNIEURS

COMMITTEE ON EDUCATION IN ENGINEERING

Journal IDEAS No. 19 December 2016

IDEAS is a publication of the WFEO Committee on Education In Engineering, addressed to engineering educators, educational officers at Universities and leaders responsible for establishing educational policies for engineering in each country. The articles it contains reflect the concern of people and institutions linked to WFEO, to provide ideas and proposals with the object of improving formation of engineering education. All the issues of IDEAS were and will be partially financed by World Federation of Engineering Organizations.

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Reflections on the 10th World Congress on Engineering Education

29 – 30 October 2015,Beirut - Lebanon

Abdul Menhem Alameddine, Chairman, Committee on Education in Engineering-World Federation of Engineering Organizations

The 10th World Congress aims to emphasize that engineering is the primary key for sustainable development in all fields and that the world needs to activate sustainable development with special focus on social, economic and environmental impacts, solve health and environmental problems, search for ways to create jobs through the development of the engineering curriculum at universities, and to raise level of electronic infrastructure to conduct the necessary research to enable sustainability in the industry, and lift barriers and challenges to find the best practices for an integrated society.

There were speakers from around the world and from Lebanon, each looking at sustainability from his point of view. We listened to the authors presenting highly professional papers tackling sustainability in all fields of engineering.

The congress suggested solutions and recommendations that can elevate the quality of education, especially in the underdeveloped countries through support from the international organizations.

Also, the congress recommended research and development programs, and suggested that work should be directed towards the integration of local needs in the engineering programs in each country, with the recommendations from the international accreditation agencies to fulfill the main theme of our committee, mobility of engineers.

I like to express my thanks and gratitude to the members of organizing committee, the Deans, their representatives and the members, thanking them for all the great work they have given to this congress to happen, without forgetting the support from the unmatchable staff at the Order of Engineers and Architects in Beirut.

Special thanks go to President Khaled Chehab and the vice president Mr. Marius Beaini of the Federation of Lebanese Engineers for their incomparable moral and financial support. Also, a great thanks is for the participating universities and their scientific committees.

The Standing of Professional Engineers And The Processes on Which It Is Founded

Dr. Peter Greenwood, Executive Vice-President WFEO
Hon FIE Aust, EngExec, FIET, SMIEEE

Dr Peter Greenwood PhD., HonFIEAust, FIET, SenMem IEEE, CPEng (Rtd), Eng Exec. Dr Peter Greenwood is an Executive Vice-President of the World Federation of Engineering Organizations. He has had a long and varied career in engineering. Dr. Greenwood was the President of IEA, Dr Greenwood was President of Engineers Australia in 2002 and 2003 and Chair of the Washington Accord from 2002 to 2007.

Abstract

This paper is strongly linked to WCEE 2015's theme of sustainability. The paper discusses the processes and infrastructure and the main stakeholders in the on-going need to produce quality professional engineers.

Trading service across and within national boundaries involves the engineering sector and the standing of its engineers. Trade is also affected by the availability and location of certified professional engineers — loosely referred to as the Mobility of professional engineers.

The World Federation of Engineering Organizations (WFEO) plays a number of important roles. The main international accreditation and certification agreements and organisations, which I will refer to as "iaca", are mostly well established and others are increasing their participation.

More countries want to improve the certification of their engineers and to acquire the capacity including appropriate processes, administrative staff and physical resources within which to operate.

"iaca" have shifted their focus from certifying individual engineers and quality control of the processes, towards cooperating with their peers and providing assistance to countries that aspire to national or international recognition.

A comprehensive model is used to illustrate what is needed and who needs to be involved.

The related activities of international engineering organisations are described and WFEO's involvement is explained.

The emerging partnership between WFEO and the International Engineering Alliance (IEA) is offered as an example of the need for close cooperation in giving help and informing governments and interested international organisations.

The need to raise awareness is shown to be very important and some of the wider issues are raised.

1. Conclusions

a. The number of countries wanting international recognition for their engineers is growing, but many lack appropriate infrastructure and processes.
b. WFEO and "iaca" are refocusing on facilitating countries to acquire appropriate capacity.
c. "iaca" are also cooperating to bring their requirements closer together and more interchangeable.
d. Donor agencies and non-engineering beneficiaries can see benefits and are very interested in participating and funding.
e. Awareness of these matters needs raising urgently by more meaningful communications, which should be helped in part by the model used in the paper to illustrate the big picture.
f. Much more progress is needed to encourage self-help, inform governments and lift our gaze to the future. Changes in the need for engineers and in the work they will do are inevitable and have to be identified and accommodated.
g. Accreditation and certification involves standards and quality control. Countries aspiring to have their engineers educated and certified to an internationally recognised standard must have or establish the necessary capacity including:
    i. Attributes of an engineering graduate and education facilities to provide graduates with them.
    ii. Competencies of a practicing professional engineer and the arrangements to provide applicants with appropriate training and experiential learning for certification.
    iii. A national accreditation system to achieve consistent outcomes among graduates from different universities.
    iv. A national registration board to certify professional engineers for professional practice.

v. A mechanism to obtain peer review against other national systems.

2. Introduction — Accreditation and Certification of professional engineers internationally

When countries trade goods and services and their companies operate across national boundaries problems can arise in the recipient country and between provider and client. In the engineering sector problems can involve engineering education and the certification of engineers. Engineering companies and their employees, as well as individual engineers, can be affected. International accreditation and certification organisations are well aware of the problems and IEA members have adapted their processes to accommodate the effect on engineering practice.

The number of engineers is rarely in balance, which is ever changing and different around the world. The ability of engineers can be seriously affected in such circumstances.

Learned societies and other agencies can facilitate engineering practice through mutual recognition agreements, which are helped by a country's membership of one of the international accreditation or certification organizations.

This paper describes what a country needs when it:

1. Is not able to accredit its engineering courses or certify its engineers or
2. Wants to establish a national system to ensure consistency or
3. Wishes to raise its national system to an international level, perhaps with a view to membership of international agreements.

3. WFEO's key roles

Two of WFEO's key roles, in this context, are firstly to help its members to improve the quality of their engineering graduates and professional engineers. And secondly, ensure that WFEO represents its members and the profession globally to international agencies. Most of these agencies are not engineering related. But they are all strongly interested in having high-quality professional engineers, available in countries that they work with.

General comments about WFEO and Mobility

WFEO has 10 Standing Technical Committees (STCs) and its WFEO-UN Relations Committee (WURC). One STC works on engineering education, another on capacity building and a third on anti-corruption and ethics. The WFEO UN Relations Committee (WURC) plays a key role liaising with the United Nations and its agencies. With all our committees' work we avoid replicating the work of our national members.

We have come to the view that the mobility of professional engineers throughout their careers involves most aspects of engineering education. This view is influenced by the needs of our national members and the international agencies we work with on behalf of the engineering profession. We complement the engineering education work of our national members, particularly their accreditation and certification activities.

WFEO has had a policy on Mobility of Engineering Professionals for many years. Part of this policy is that WFEO will publicize the work of all the organizations involved through its website and other opportunities. Several papers have been issued, which are all on the WFEO website in the Education Committee section.

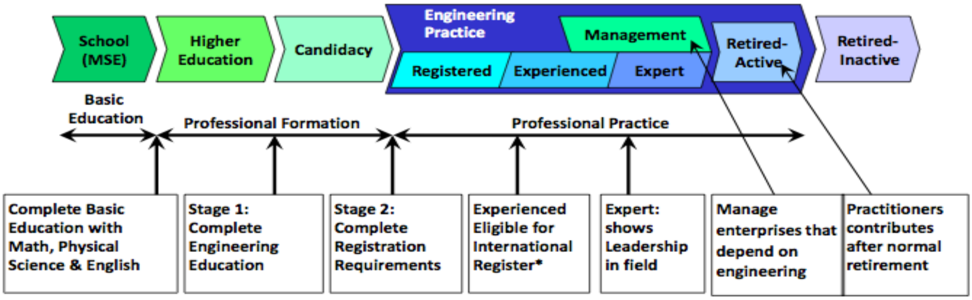
Accreditation and certification of professional engineers

WFEO has very important work to do on this topic. Our members in some regions urgently want to improve the quality and recognition of their engineers. Even our members with established accreditation and recognition processes see an important need for compatibility across regions, which will serve in place of a world approach for the short to medium term.

The same urgency, reasoning and needs apply to the development banks, regional development agencies and government agencies like the World Trade Organization. The availability and ability of engineers affects agency success rates.

My paper at WCEE 2013 was a scorecard based on Fig 1., which describes an engineer's career with the typical first two stages consisting of engineering education and formation (meaning training and experience) needed for certification or registration (which I will use in the paper). After the formation an engineer is said to be capable of independent ethical professional practice. The remaining stages are about gaining more experience, perhaps becoming a technical expert or an engineering manager.

Finally the engineer moves into retirement and often continues some work or a contribution to the profession through a learned society.



Zone						

Figure 1. Engineering Practitioner Career

(Original diagram courtesy of Prof. Huw Hanrahan (ECSA), with changes by Dr Peter Greenwood, EA)

In broad terms I reported progress across the diagram — the whole-of-career journey, based on life-long-learning over the three colored zones — in terms of what we were doing "Now" and what we needed to do "Next" (into the future). In 2013, I believed that internationally and in many countries Stages 1 and 2 were at a sustainable level and working reasonably well — the "Now". Much more work was needed on the other four stages for which I made a number of comments and suggestions — the "Next".

Recent developments

In the last two years, many things have happened in various parts of the world, and many of them involve the quality, development and number of available engineers around the world. I have based my paper for WCEE 2015 on some of those changes involving WFEO. A good example is WFEO's cooperation with the International Engineering Alliance (IEA). For the moment we have shifted our main focus away from individual engineers, more to the capacity (or infrastructure) building that is vital to the accreditation and certification stages in an engineer's career. I will show you what capacity institutions and their processes need and how they fit into the overall picture. This will result in a need for physical and related resources including funding.

The three major future actions evident in 2015 are:

1. Within the engineering sector — universities, learned societies and engineering industry — there is a big internal communication problem about the nature of engineering work and the meaning and extent of regulation of professional engineers. Personal pride and aspirations must be included. Without meaningful communications at best progress will be suboptimal and at worst we will fail.
2. We need to re-engineer the relationship between learned societies, universities and industry. Each part of the engineering sector must be involved in defining the future nature of engineering work, the qualifications and competencies needed and how to deliver training. Estimating the number of engineers needed is difficult but some indication is essential. We'll be lucky if the answers are right but at least they would give some conception of what might emerge.
3. When we have informed ourselves and reached some sort of consensus, we can make a start on informing governments and the general public.
4. It sometimes seems that trust between governments and engineers has been lost. The public can't believe or understand what governments or engineers say, so they demand detailed explanations they can't understand, which is another communication dilemma.

The profession has to identify the key players with whom it needs to cooperate.

Understanding the accreditation and certification "Big Picture" .

The starting point for my discussion is a general model to help our understanding.

The model represented in Figure 2 explains the overall picture of actions and agencies that work towards the licensing and certification of professional engineers. It shows the organizations involved both nationally and internationally.

It is said that only about 20% of engineering work requires licensing. Some countries reserve the title Engineer to certified professional engineers. I will use "registration" and licensing to mean engineers in the 20% and "certification" for engineers in the 80%. The latter may have a number of personal or other reasons for becoming certified.

The model shows the intricacies and importance of its components for aspirants to institutional membership of the one of the international accreditation and registration/certification agencies. It should also be of use to the many people who want to understand the basis of the validity of their standing as professional engineers or aspirants. Engineers and non-engineers, who have heard of the accreditation accords and related certification organizations, may also want to understand what they are and what they do. And finally the model shows in general terms, the infrastructure capacity needed from providers.

The **NOW** section on the left-hand side of the vertical line shows all the stages in the development of competent professionals engineer, the blue shapes, up to the time when they are accepted as ready for independent practice. The red, yellow and orange shapes show the national and international agencies involved. The agencies ensure that the education, training and experience gained meet the standard required for national or international practice. Generally such models are working satisfactorily in whole or in part and they continue to improve. Some consolidation is needed in the **NOW** section to increase participation. Participants will need appropriate responses to adapt to changing circumstances.

The **FUTURE** section, to the right-hand side of the vertical line, shows the areas of the model where further work is needed to increase the availability of facilities and lift the standard of the later periods of an engineer's career.

The complete model, in Figure 3, shows we need much more work in the **FUTURE** section l.

The complete diagram describes a country licensing professional engineers with all its agencies in place in partnership with the international accreditation and certification agencies ("iaca"). This outcome is also the aim of WFEO and the reason why it is cooperating with engineering sector and the "iaca".

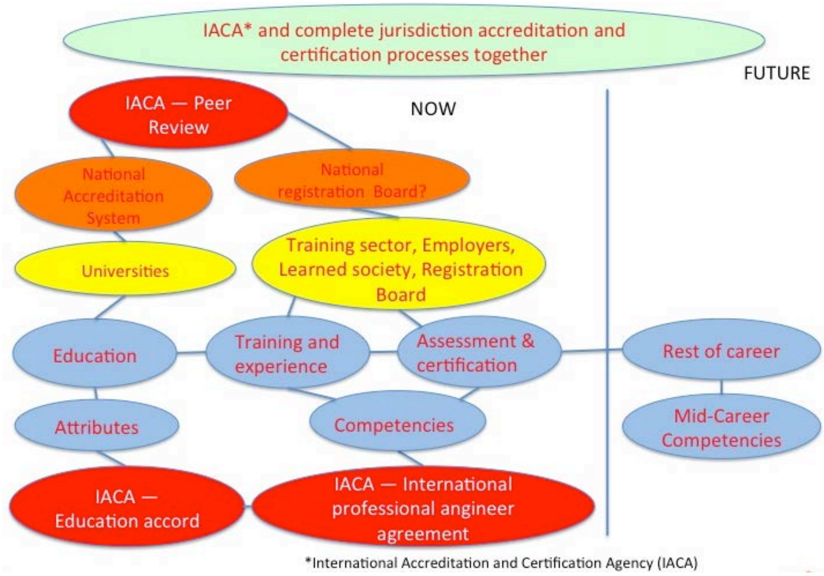


Figure 2. The making of an internationally recognized professional engineer — present picture

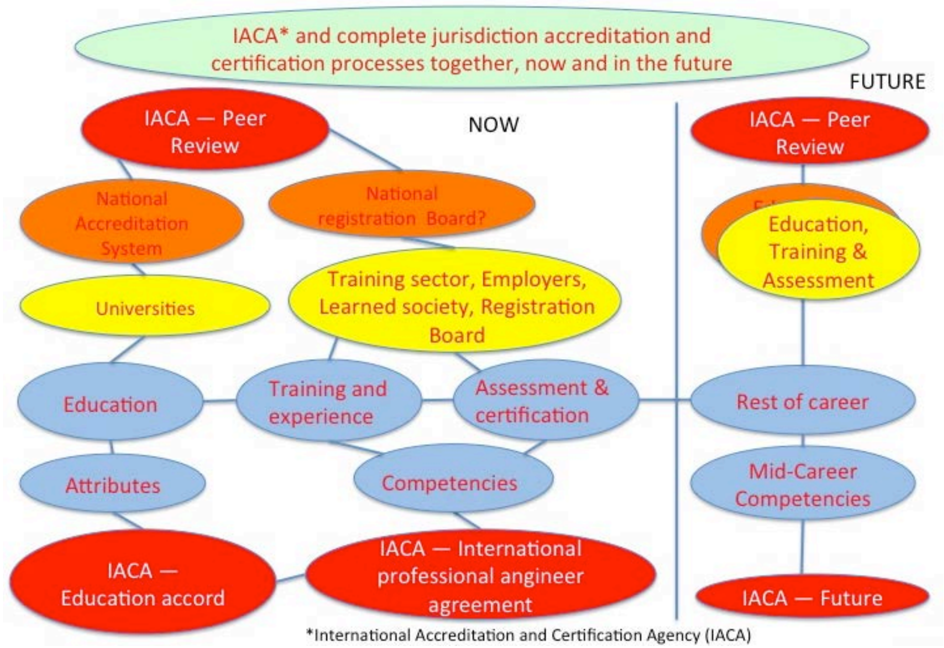


Figure 3. Complete picture — consolidation and the future

Non-engineering agencies

We must keep in mind the international significance and importance of the recognition and quality of professional engineers with respect to migration and work mobility between countries. Apart from the impact on the countries involved and the engineering sector in general, the recognition and quality of professional engineers is of considerable importance to international humanitarian, development, funding and trade organizations. WFEO has a major role to play with the non-engineering sectors, representing the profession and engineering learned societies to these sectors' international agencies.

The International Federation of Consulting Engineers (FIDIC) is WFEO's counterpart, representing companies providing engineering consultancy and other services in these sectors. It is an example of the business and company side of the engineering sector, which is very important to the work of the international agencies listed above.

WFEO plays a second role with some non-engineering sectors, offering a technical contribution of skills and information from its technical committees and networks — notably WURC and the Standing Committee on Engineering and the Environment (CEE) as well the other STCs mentioned earlier. A third role is to use its website and networks to publicise the work of "iaca".

The main international engineering learned societies

Regions of the world, loosely based on continents, already have representative engineering organizations. The Pan American Union of Engineering Organisations (UPADI), the European Federation of national Engineering Associations (FEANI), the Federation of African Engineering Organizations (FAEO), the Federation of Arab Engineers (FAE) and the Federation of Engineering Institutions in Asia and the Pacific (FEIAP) are the main ones. They are already important members of WFEO, mainly because of their learned society function. They also have a second function playing a part in certifying professional engineers. Some are also involved with their members' accreditation of engineering education courses. There are other, usually smaller, international learned society groups, which may have the second function at a formative stage or at a local level.

WFEO relates to the learned society roles and the accreditation and certification roles of its members differently. WFEO does not get involved directly in standards setting.

International Engineering Alliance (IEA) members are independent of government (with the exception of the APEC example described below) relying on member funds. IEA members accredit engineering education programs and certify professional engineers in their countries, as well as maintaining consistency across IEA's membership by periodic peer assessment. IEA is the only global agency with membership open to countries in all geographic regions.

The IEA comprises two agreements for professional engineers, the International Professional Engineer Agreement (IPEA) and the APEC Engineer Agreement (APECEA). APEC is the Asia-Pacific Economic Cooperation forum for governments in the region. The engineering certification organisations of the APEC economies form the APEC Agreement, the members of which are linked to their governments but not generally funded by them. The APECEA professional engineer standard is equivalent to the IPEA standard.

The APEC Engineer Agreement is working with APEC to re-establish its links to the APEC secretariat. Keen interest in the APEC Engineering standard has re-emerged in APEC because of the growth in free trade agreements linked to APEC and the economies wanting to join a trade agreement.

IEA's work is on standards and consistency of processes that use the standards. WFEO has been cooperating closely with IEA for some years, as it adopted a more outward-looking approach. We expect to have a formal agreement by the end of 2015.

The European Network for Accreditation of Engineering Education (ENAEE) grew out of the Bologna Declaration and the Bologna Process. It is the European equivalent of the IEA's Washington Accord. ENAEE and FEANI represent the European region, which comprises 47 members of the European Higher Education Area (EHEA) including 27 European Union (EU) member countries.

ENAEE and FEANI have equal standing with their IEA counterparts — the Washington Accord, the International Professional Engineer Agreement and the APEC Engineer Agreement. All are working towards harmonizing their respective requirements for professional engineers, to avoid confusion and improve interchangeability.

Cooperation between the regional and global organizations is very much helped by many common memberships of countries across all these organizations.

The IEA and ENAEE could join WFEO in an associate role, which would be acceptable to WFEO as long as the relationship did not endanger the independence and integrity of their standards and processes.

FEIAP has produced an Engineering Education Guideline, originally written to help a small number of its members to achieve the Washington Accord level. The Guideline is based on the Engineers Australia Accreditation System. UNESCO's Jakarta Office has endorsed the Guidelines and called for its widespread acceptance. This development needs some clarification to avoid confusion between programs accredited under the guideline and those accredited under the Washington Accord.

UNESCO has provided some funding to assess the standard of some FEIAP countries aspiring to improve the quality of their engineers and educational institutions. This will be an opportunity to assess the use of the Guideline.

UPADI has begun an initiative on accreditation and has sought the involvement of WFEO's Committee on Education in Engineering.

Capacity or Infrastructure Building: WFEO, WFEO's STCs and international agencies

One aspect of our agreement with IEA is about national accreditation and recognition processes that require support and funding from government or other agencies to provide and administer. The processes might be called "soft" capacity or infrastructure, which is an integral part of the physical infrastructure of universities, training facilities, learned societies and regulatory offices.

Government assistance is also needed for the physical infrastructure. Aid agencies and development banks are very interested in funding this sort of national and regional capacity. WFEO's Committee on Capacity Building (CCB) is well established to contribute with its Capacity Building Guidelines and its network of interested participants. Contributions are also coming from CEIE on the education and university aspects through its networks and conferences. The Committee on Anti-Corruption (CA-C) contributes through its model code of ethics and extensive training programs from its partner, the Global Infrastructure Anti-Corruption Centre (GIACC) based in England. WURC is also in a unique position to present information on this work to UN committees and to a wider international audience.

Our common ground with IEA

In exchanges over recent years, IEA and WFEO have developed similar interests with the same obligations to their members and prospective members. We exchanged letters of understanding, then a memorandum of understanding last year. In building a partnership we are helped by close cooperation between senior office bearers from both our organizations. From these discussions, the synergies of need, experience and the ability to tap resources made a formal agreement very much appropriate. Each of us has established a team to work on the form of an agreement, with the document to be signed by the end of the year.

An IEA member has been working closely with us, attending our last Executive Council meeting and the meetings to progress a major project, the Africa Catalyst Project. IEA Council immediate-past chair has also been an active long-standing facilitator of these moves towards an agreement. As well, last year he joined WFEO's team doing an annual assessment of the STCs to gain an understanding of their work.

The Africa project is a good example of the work we will do under the agreement. Good accreditation and recognition arrangements can't be achieved without institutional capacity, which in turn requires plans, the involvement of political agencies and a major development agency. This is happening with the Africa Catalyst Project through the FAEO and appropriate agencies. WFEO has played its part but the key point is that African engineers themselves are driving the project. WFEO also has a team helping, which has obtained strong encouragement from a British government-funding agency.

In 2013 WFEO's President signed the Abuja Declaration setting out details of cooperation on mobility in the Sub-Saharan region.

WFEO and IEA independently have also identified Southern South America, the Middle East and others as regions with similar needs but different circumstances. In the last mentioned, the Federation of Arab Engineers has taken some initiatives, using some internationally recognized processes. Interest is growing in South America in Brazil and Peru. The latter has become a provisional member of the Washington Accord.

Awareness

Although many countries are aware of the main international accreditation and recognition systems, they are not clear about the extent of their jurisdictions or how many countries are involved in each system. My advice is that the IEA is the biggest in terms of recognition, membership and global jurisdictional coverage, although membership seems to be growing in most "iaca".

In engineering practice a providing country or company has to be aware of the requirements for international professional engineers or those of the receiving country — if there are any. The receiver country needs to be aware and understand the certification of engineers working in its jurisdiction. Although some of these matters are known and dealt with there are many countries where they are not, because of lack of knowledge, processes and the capacity itself.

Another global aspect, the current shortage of engineers in many developed and less-developed countries, is very important. Some other developed countries, in the EU for example, have a surplus of engineers although they would not like to lose them permanently. Loss of any professional from any country, is reflected in a lost investment in human capital. An engineer who returns to his country after gaining training or experience brings back that investment with interest. In the case of developing countries the needs and shortages, and the impact of migration, are much greater, affecting their economic and technical development.

Although we can't solve the political matters, we can work to improve the quality and recognition of professional engineers. The WFEO/IEA Agreement and our close cooperation with all international accreditation and certification agencies will, I am sure, have a very significant impact.

END

Engineering Ethics and Sustainability

W.E. Kelly

George Mason University, Fairfax, Va USA

Dr. Kelly retired in January 2015 as Director of External Affairs at the American Society for Engineering Education (ASEE). At ASEE, his responsibilities included the Engineering Deans Council, international activities, and ASEE's ABET accreditation responsibilities. Prior to joining ASEE in September of 2007, he was a Professor of Civil Engineering at the Catholic University of America in Washington, D.C. where he served as Dean of the School of Engineering from 1996-2001. He is currently a member of the NAE Center for Engineering, Ethics, and Society Advisory Group, the ASCE Committee on Sustainability and the Board of Directors of the Civil Engineering Certification Board. He is a Fellow of the American Society of Civil Engineers and ABET.

Abstract

Engineering ethics and sustainability are important components of engineering education and professional practice. Both are included in the International Engineering Agreements Graduate Attributes and Competencies that are the basis for accreditation under the Washington Accord. The purpose of this paper is to review where we are in infusing sustainability ethics into engineering education focusing on Washington Accord signatory countries and to briefly describe an expanded U.S. National Academy of Engineering Online Ethics Center that should be a valuable resource for programs infusing ethics and sustainability into engineering curricula.

KEYWORDS: *accreditation, ethics, sustainability*

1. Introduction

The purpose of this paper is to review ethics and sustainability in engineering education from a top down global to local perspective. The focus is on the World Federation of Engineering Organizations (WFEO) and the International Engineering Alliance (IEA). The IEA and WFEO recently signed a MOU and are currently developing an agreement to work together on engineering accreditation.[1] Accreditation sets the standard for what engineering graduates should know and be able to apply. The U.S. National Academy of Engineering (NAE) is expanding its Online Ethics Center (OEC) and with increased global coverage should be a valuable resource for teaching and learning the ethics of sustainability in engineering practice. Codes of ethics have been important drivers of sustainability and sustainable development in engineering and the ethical aspects of sustainability and sustainable development are receiving increasing attention by academics and practitioners.

2. Knowledge Expectation

Ethics and sustainability are prominent in the UNESCO report on Engineering; see for example articles by Bugliarello, Ridley, Didier and others.[2] Byrne et al reviewed sustainability expectations for engineering graduates in the context of codes of ethics for most of the Washington Accord signatories.[3] This paper builds on the most recent Byrne paper.[4]

2.1 WFEO ethics and sustainability

Sustainability is explicitly included in the WFEO Model Code of Ethics under Canon 4 protection of the natural and built environment.[5] The WFEO Model Code of Practice for Sustainable Development and Environmental Stewardship provides a comprehensive approach to sustainability in engineering practice.[6] The WFEO is working with the IEA to develop a MOA to work together to mentor countries wanting to join the IEA.

2.2 IEA Ethics and Sustainability

The IEA Graduate Attributes and Competences are the foundation for accreditation of engineering programs under the Washington Accord (WA). To be recognized under the Washington Accord the accreditation process must ensure that the attributes of graduates of a signatory’s programs are substantially equivalent to the IEA graduate attribute exemplars. Graduates are expected to be able to demonstrate both knowledge and competencies.

WK7: Comprehension of the role of engineering in society and identified issues in engineering practice in the discipline: ethics and the professional responsibility of an engineer to public safety; the impacts of engineering activity: economic, social, cultural, environmental and sustainability

According to the IEA Glossary of Terms, comprehension is synonymous with understanding.[7] The American Society of Civil Engineers Body of Knowledge (2nd edition) uses Bloom's taxonomy with comprehension being level 2 and application level 3.[8]

Engineering graduates from all programs accredited under the IEA Washington Accord can be expected to have an understanding of both ethics and sustainability in the context of engineering practice in their field.

Table A1 summarizes some of the phrases in accreditation criteria that reflect this requirement. Most of the statements use understanding for comprehension.

At the Professional Level, practicing engineers are expected to:

WA7: Understand and evaluate the sustainability and impact of professional engineering work in the solution of complex engineering problems in societal and environmental contexts. (WK7)

This is a level 4 or 5 Bloom outcome building on the knowledge base from formal education. The key word here is complex; an appreciation of complexity will only be acquired with practice. Evaluate is reserved for level 6 in the ASCE BOK2. At the professional level we have

WA8: Apply ethical principles and commit to professional ethics and responsibilities and norms of engineering practice. (WK7)

This attribute can be interpreted as level three. The new program criteria for ABET accredited civil engineering programs requires level three for both sustainability and ethics; graduates must be prepared to include principles of sustainability in design and to analyze issues in professional ethics.[9] However, program criteria are curriculum requirements not outcomes so the content must be in a program but there is no expected assessment of student understanding or comprehension.

At this point, the expectation for most WA engineering graduates is level 2 - comprehension - but there may be other requirements for specific fields similar to the ASCE program requirements.

3. Educational Approaches

In this paper we are particularly interested in how ethics and sustainability are being integrated in engineering education. Kibert and coauthors do this in a book that could be used as a textbook or reference for practitioners.[10] It could also be a text for a full course in sustainability ethics.

Both sustainability and ethics could be included as modules in courses throughout a program from an introductory course to a culminating design courses and there a many examples of this being done. Mulling et al described their experience with a sustainable design project in a first year course. Reported student feedback indicated that ethics and sustainable design were effectively combined.[11] Dawash et Al describe their efforts to integrate sustainability and environmental ethics in a construction engineering program.[12] Robinson and Sutterer describe their approach to integrating sustainability into a civil engineering program.[13] They start with a discussion of sustainable development in the ASCE Code of Ethics in an introduction to civil engineering course. Veeraghanta and Frost describe their experience integrating sustainability and ethics in a first year course at the University of Utah.[14]

There is no shortage of resources for teaching sustainability and ethics. Engineering ethics case histories developed by the UK CETL are available on their web site and include sustainable development.[15] The CETL case study on sustainability ethics deals with heritage sites and is on a Leeds University site.[16] Ashley discusses the role of the civil engineer in: engineering ethics and major projects in the context of the sustainability challenge from Prince Charles.[17] The ICE has an Ethics Toolkit for practitioners and academics.[18]

In Australia, engineering ethics and sustainable development have been addressed in engineering education for more than 20 years, see for example the 1995 paper by Beder.[19]

The work of Byrne and his colleagues in Ireland has already been mentioned. Byrne describes his experience at University College Cork with ethics and sustainability in a first year introductory module in chemical engineering.[20]

Reid in a doctoral thesis provides a comprehensive review of the evolution of ethics and sustainability engineering education in New Zealand engineering education as background for designing an undergraduate module at the University of Auckland.[21]

Masud et Al discuss generally what is needed to introduce sustainability into engineering education in Malaysia.[22]

The challenge may not be so much resources but how to teach ethics and to a lesser extent sustainability. Ethics and to some extent sustainability require that instructors not rely exclusively on lectures - still the predominant mode of instruction in engineering.

4. The U.S. National Academy of Engineering Online Ethics Center

The NAE Online Ethics Center recently (2014) began an expansion project funded by the U.S. National Science Foundation (NSF) to become to the "go to" place for engineering ethics.[23] The coverage goes beyond engineering ethics but engineering ethics is already a strong component of the OEC and this component will be strengthened particular the international coverage with the expansion.

The University of Delaware's Center for Science, Ethics and Public Policy (CSEPP) is leading the international component of the expansion. The goal is to incorporate a more comprehensive international component in the center resources. This effort is seeking to identify a cohort of international collaborators to contribute to the center.[24]

During fall 2014, the OEC surveyed faculty to determine what is most important in teaching ethics to science and engineering students.[25] There was a strong response from engineering faculty including members of the American Society for Engineering Education (ASEE) Engineering Ethics Division. The Engineering Ethics Division is one of the largest Divisions in ASEE with over 1100 members. For faculty members that have taught ethics and those that have not, the most important resource for teaching ethics is case histories. A number of the case histories on the OEC are detailed including instructor notes and can be described as off the shelf and ready to use. More are needed and there are relatively few that deal with sustainability.

5. Summary

Sustainability and sustainable development are prominent in the WFEO Model Code of Ethics and the codes of ethics of many of the IEA members. Graduates of programs recognized under the Washington Accord are expected to have at least an understanding of professional ethics and sustainability in the context of engineering practice in their field. Although there is no lack of resources for teaching and learning sustainability ethics, these resources, with some exceptions, are not easily accessible for faculty needing a module for a particular course or topics. The U.S. National Academy Online Ethics Center aspires to be the go to place for engineering ethics and if successful should greatly improve accessibility and usability. The WFEO Committee on Education in Engineering could help by assisting the OEC in reaching out broadly to WFEO members to share resources on teaching and learning sustainability ethics and to solicit a broad range of case histories that illustrate engineering practice globally.

References

[1] WFEO IEA MOU http://www.engineerscanada.ca/sites/default/files/iea_wfeo_mou_24_14.pdf Accessed May 7, 2015

[2] UNESCO Engineering: Issues Challenges and Opportunities for Development, http://unesdoc.unesco.org/images/0018/001897/189753e.pdf accessed April 7. 2015

[3] Byrne et al Engineering Education for Sustainable Development: A Review of International Progress http://www.ucc.ie/archive/isee2010/pdfs/primer.pdf Accessed April 17, 2015

[4] Edmond P. Byrne, (2012),"Teaching engineering ethics with sustainability as context", International Journal of Sustainability in Higher Education, Vol. 13 Iss 3 pp. 232 - 248 Permanent link to this document:http://dx.doi.org/10.1108/14676371211242553

[5] WFEO Model Code of Ethics http://www.wfeo.org/ethics/ Accessed May 7, 2015

[6] WFEO Model Code of Practice for Sustainable Development and Environmental Stewardship http://www.wfeo.org/sustainabledevelopment/ Accessed January 11, 2016

[7] IEA Glossary of Terms http://www.ieagreements.org/IEA-Extended-Glossary.pdf Accessed May 1, 2015

[8] ASCE Body of Knowledge for the 21st Century 2nd Edition, http://www.asce.org/civil_engineering_body_of_knowledge/ Accessed May 2, 2015

[9] ABET Proposed Criteria 2015-2016 http://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2015-2016/ Accessed May 2, 2015

[10] Kibert et al Working Toward Sustainability: Ethics Decision Making in a Technological World, http://www.wiley.com/WileyCDA/WileyTitle/productCd-0470539720.html Accessed May 2, 2015

[11] Mullin et al 2006-958: SUSTAINABLE DEVELOPMENT DESIGN PROJECTS FOR ENGINEERING FRESHMEN, https://peer.asee.org/sustainable-development-design-projects-for-engineering-freshmen Accessed January 11, 2016
[12] Dawash, M.M et Al Incorporating Sustainable Development and Environmental Ethics in Construction Engineering Education, http://www.laccei.org/LACCEI2010-Peru/published/CE168_Darwish.pdf Accessed May 2, 2015
[13] Michael Robinson, P.E. and Kevin Sutterer, P.E Integrating Sustainability into Civil Engineering Curricula 2003 https://peer.asee.org/integrating-sustainability-into-civil-engineering-curricula Accessed January 11, 2016
[14] Veeraghanta, S.V., and Frost, J.W. Integrating Sustainability Within Ethics Discourse: A Freshmen Perspective https://peer.asee.org/integrating-sustainability-within-ethics-discourse-a-freshman-perspective January 11, 2016
[15] IDEA CETL Engineering Ethics - case studies http://gdee.org/node/79 Accessed January 11, 2016
[16] University of Leeds, Sustainability versus heritage http://exchange.ac.uk/downloads/scholarart/ethics/heritage.pdf Accessed March 30, 2015
[17] Ashley, R. The Role of the Civil Engineer in Society: Engineering Ethics on Major Projects http://www.engineeringnaturesway.co.uk/resource/the-role-of-the-civil-engineer-in-society-engineering-ethics-and-major-projects/ Accessed March 30, 2015
[18] ICE Ethics Toolkit http://www.ice.org.uk/Information-resources/Document-Library/Civil-engineering-Ethics-Toolkit Accessed March 30, 2015
[19] Beder, S Engineers, Ethics, and Sustainable Development http://www.herinst.org/sbeder/esd/Florencetalk-2.html#.VRlDjOGLCZF Accessed March 30, 2015
[20] Byrne, E.P. Teaching Engineering Ethics and Sustainability http://www.ucc.ie/en/processeng/staff/academic/ebyrne/publications/eesd10/ByrneE-Teachingengineeringethicsandsustainability.pdf Accessed January 11, 2016
[21] Reid, M.S. Doctoral Thesis The Design and Implementation of an Ethics Module within an Undergraduate Engineering Studies Curriculum, University of Auckland http://aut.researchgateway.ac.nz/bitstream/handle/10292/1304/ReidM.pdf?sequence=3 March 30, 2015
[22] Masud M.H. et al Engineers' Obligation Towards Sustainable Environment, https://www.academia.edu/1782144/Engineers_Obligations_towards_Sustainable_Environment Accessed March 30, 2015
[23] CEES Becoming the Online Resource Center for Ethics Education in Engineering and Science, http://www.nae.edu/Projects/CEES/57196/OECexpansion.aspx Accessed May 2, 2015

[24] University Delaware, International ethics, http://www.udel.edu/udaily/2015/oct/research-ethics-101514.html Accessed May 2, 2015
[25] OEC Request for Faculty Feedback on Teaching Ethics in Science and Engineering, http://www.nae.edu/Projects/CEES/57196/OECexpansion/122448.aspx Accessed May 2, 2015

APPENDIX

Table A1 Comparison of Knowledge Outcomes IEA Signatories

IEA Signatory	**WK7: Comprehension of the role of engineering in society and identified issues in engineering practice in the discipline: ethics and the professional responsibility of an engineer to public safety; the impacts of engineering activity: economic, social, cultural, environmental and sustainability**
Australia Engineers Australia	Understanding of the scope, principles, norms, accountabilities and bounds of sustainable engineering practice in the specific discipline.
Canada Engineers Canada	Impact of engineering on society and the environment: An ability to analyze social and environmental aspects of engineering activities. Such ability includes an understanding of the interactions that engineering has with the economic, social, health, safety, legal, and cultural aspects of society, the uncertainties in the prediction of such interaction.
China Taipei IEET	Understanding of professional ethics and social responsibility.
Hong Kong The Hong Kong Institute of Engineers	A knowledge of the impact of engineering technology solutions in a societal and global context with particular reference to the environment and sustainable development.
India NBA	Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of need for sustainable development.
Ireland Engineers Ireland	Understanding of the need for high ethical standards in the practice of engineering, including the responsibilities of the engineering profession towards people and the environment.

Japan JABEE	Understanding of the effects and impact of engineering on society and nature, and of engineers' social responsibility (engineering ethics).
Korea ABEEK	A broad understanding of the impact of engineering solutions in economic, environmental, and societal context.
Malaysia	Understand the impact of professional engineeringsolutions in societal and environmental contexts and demonstrate knowledge of and need for sustainable development. Apply ethical principles and commit to professional ethics and responsibilities and norms of engineering practice.
New Zealand Engineers New Zealand	Comprehension of the role of engineering insociety and identified issues in engineering practice in the discipline: ethics and the professionalresponsibility of an engineer to public safety. Theimpacts of engineering activity: economic, social,cultural, environmental and sustainability.
Russia	Studies in humanities and socioeconomic sciences must provide graduates with the appropriate knowledge in social, economic, legal issues and professional ethics, foster commitment for sustainable development, health and safety issues.
South Africa	Demonstrate critical awareness of the sustainability and impact of engineering activity on the social, industrial and physical environment. Demonstrate critical awareness of the need to act professionally and ethically and to exercise judgment and take responsibility within own limits of competence.
Singapore	Understand the impact of engineering solutions in a societal context and to be able to respond effectively to the needs for sustainable development; understand

	professional, ethical and moral responsibility.
Sri Lanka	It must be ensured that the students are made aware of the role and responsibilities of the professional engineer in society by exposing them to ethics, equity, public and worker safety, and concepts of sustainable development.
UK JAB	The engineering subjects should be taught in the context of design (see Annex B – Design in Degree Programs), with appropriate account of issues of sustainability (see Annex C – Sustainable Development in Degree Programs) and construction, so that each forms a continuous and integrating thread running through the program. Programs should expose students to a thorough mixture of analysis, synthesis and conceptual design, and – through contact with other issues – they should be stretched to ensure development of their capabilities to operate at a high intellectual level, including the exercise of judgment.
USA ABET	An understanding of professional and ethical responsibility

To Bridge The Gap Between The East And The West

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Dr. Xila Liu, Chair Professor of Civil Engineering Department at Shanghai Jiaotong University (SJTU), is Executive Member (National Member of China) of the World Federation of Engineering Organizations WFEO and Executive Member of the Federation of Engineering Institutions of Asia and the Pacific (FEIAP). He is also the author or co-author of 5 books and about 400 articles in various technical journals, conference proceedings, and symposium volumes. His major research topics include: Constitutive Modeling of Concrete, Safety Analysis of Structures, Durability Modeling of Structures, Knowledge-based Systems for Structural Design and Damage Assessment. He was invited as the principal draftsman on "The Development Strategy of Structural Engineering in China" (1991) and "The Development Strategy of Engineering in China" (1999) by the National Natural Science Foundation of China (NSFC). In 2004, he was also invited as the first principal draftsman on "2020: Research on The Development of Engineering Technology in China". Since his outstanding contribution he received an honorary certificate by the China Association for Science & Technology (CAST). In 2006 and 2008, he was invited as Chair Scientist to write the 2006 and 2008 Annual Progressive Reports of Science and Technology in Civil Engineering for China Civil Engineering Society (CCES) respectively.

1. INTROUCTION

It is well known, as Professor Joseph Stiglitz, the Nobel economic prize winner in 2001, mentioned that "The two major events which will affect the human civilization process in the 21st century are the new technological revolution led by the U.S. and the China urbanization."(Liu and Ang, 2014) It is very clear that, in the new century, the most huge construction projects will be built in the developing countries, but till now most of advanced research projects have still been done in the developed countries. The problem is that so many important practical data were not collected in developing countries and a large number of new technical words are produced in developed countries. From the global technical point of view it only made slow progress with respect to the urbanization process. At the first joint International Conference on Sustainable Development of Critical Infrastructure (IC-SDCI 2014) by both China Civil Engineering Society (CCES) and American Society of Civil Engineers (ASCE), which was hold at Shanghai Jiao Tong University during May 16-18 2014 (Figure 1), more than one hundred exports from all around world obtained a consensus view, which is “To bridge the gap between developed countries and developing countries”.

Figure1.Opening plenary meeting of IC-SDCI 2014

There are three aspects should be mentioned. First, the urbanization process of developing countries has become one of the leading roles in the world, and it is also a good opportunity to learn advanced techniques from developed countries. Second, not only the positive experience should be learnt from developed countries but also the negative lesson in developed countries should be collected. Third, no matter from the West or from the East, people should be “thinking in global, working at local”. Considering the “global” should be the core of the sustainable development of whole world. In the present paper the three aspects will be introduced in more detail.

2. URBANIZATION PROCESS OF DEVELOPING COUNTRIES HAS BECOME ONE OF THE LEADING ROLES IN THE WORLD

Unless the development of science has only one constrain, which is the nature, the development of engineering has two constrains, which are both nature and society (Liu, 2004, 2006, and 2008). In general, for most of developing countries, when the urbanization ratio reaches 30% the personal income will be increasing sharply. In China the urbanization ratio has reaches 54.77% in 2014. According to the population of 1.3 billion China has become the largest construction field in the world. As an example, Shanghai has been located in the midst of developing infrastructure systems for the entire China, which includes almost all types of infrastructure systems, from buildings (Figure 2), bridges (Figure 3) and tunnels, high-speed rails and super-highways, to harbor (Figure 4), nuclear power plants, and wind and solar energy systems(Liu and Ang, 2014).

Figure 2.View of Pudong’s Lu JIaZui

It should be recognized that, to develop infrastructure systems Chinese have to consider their own geographical and environmental constraints. In China the very heavy population load and very critical energy resource limitation must to be considered during the urbanization process. To simply copy the western urbanization pattern will be very dangerous. Any mistake during urbanization process happened in China may produce many difficulties for whole world (Liu, 2004, 2006, and 2008).

Figure 3. Dong Hai Bridge in Shanghai

It should be also recognized that there is a very wide technical developing space and opportunity for China to develop own systems. For example, among the construction projects of transportation systems it may be the better choice to build more high-speed rails instead of too intensive super-highway networks. In the near future the transportation system construction in China should focuses on public service.

Figure 4. Shanghai Yang Shan Harbor

From history it can be found that Chinese culture is comprehensive and Chinese emphasis an inclusive culture. In the new century Chinese have certainly to learn many contributions from western technological revolution and Chinese also recognize that most of critical construction projects will be constructed in the east. In this case, many advanced research projects on theory, experiment and computation, which are proposed from application, are shifting from west to east. At present there are two barriers existing. One is that even so many critical infrastructures have been finished in China, only a few of them can be introduced to all of world. There may be some language problem, from author's point of view however, many managers in China may have no enough consciousness to work for the whole world. Another barrier is that many engineers in China have not paid attention to data collection. For example, the author was responsible for an key project "Application Research on Intelligent Decision Making Systems in Construction"(1988~1993), which was supported by the National Natural Science Foundation of China (NSFC). In the project a group of professors from South-western Jiao Tong University successfully fulfilled a monitoring system on highway bridges in Guangdong province in 1990, which should be the first monitoring system on highway bridges in China. Unfortunately, until now, it seems almost 25 years passed, there is no any databank remained. It should be emphasized that, in any case, the practical data from life-cycles of projects are primary, which are very important for future research and development, all related data should be carefully collected especially in developing countries (Liu, 2004, 2006, and 2008).

From new published papers of developed countries many new technical words can be found and they are quickly spread in developing counties. In fact they may not be new in practical engineering. For example, several years ago, a new technical word "performance based design of structures" is getting more popular in a seismic engineering. Starting from America, passing through Japan, finally in become very hot technical topic in China. In fact it is not new in China. Almost in the 50s of the last century, a very complete structural reliability theory from Russia has been introduced to China. Even in textbook, it has been shown clearly in China. The Russian "reliability" includes Safety, Serviceability, and Durability. The meaning of "performance based design of structures" is structural serviceability. Recently a new word "resilient structures" is introduced more often, in fact, the "resilient" means, from time domain, how much time is need to recover the structural function after an earthquake. After "911" of 2001, some new words "structural robustness" or "structural vulnerability" become more popular, actually it means, from structural topology, to measure the ratio between a local damage to partial function loss. No matter the "resilience" or "robustness (vulnerability) the key point is how to guarantee the "safety" and "serviceability".

3. To Learn Negative Lessons From Developed Countries

Good at learning is one of important keys for developing countries, to make every effort to learn from developed counties is necessary. But a developing country may have some constraints, such as environment and natural resources. The methodology on dialectics is also important. In another words, for developed countries, it should be noted that not only the positive experience should be learnt from developed countries but also the negative lesson.

25 years ago, there was a big argument raised in public of China, which is "should every family need at least one private car?" Many technical experts gave the answer is "NO". The reason is simple, the heavy population load of 1.3 billion people and limited energy resources must be considered. Even though many technical delegation groups came to China to introduce their intelligent transportation systems to overcome the traffic jams people stilldoubted if it was really necessary to produce so many private car in China. Should Chinese people have to follow the same negative cycle happened in developed countries, such as the air pollution, shortage of energy resources, heavy traffic jams? Now it has been proved Chinese people are suffering almost the same problems happened in western world as predicted (Figure 5 and Figure 6). According to a recent survey in 2013,it has not been optimistic,that the number of car owner ships in China has exceeded over 200 million, which only happened in U.S and China in the world (Liu and Ang 2014).

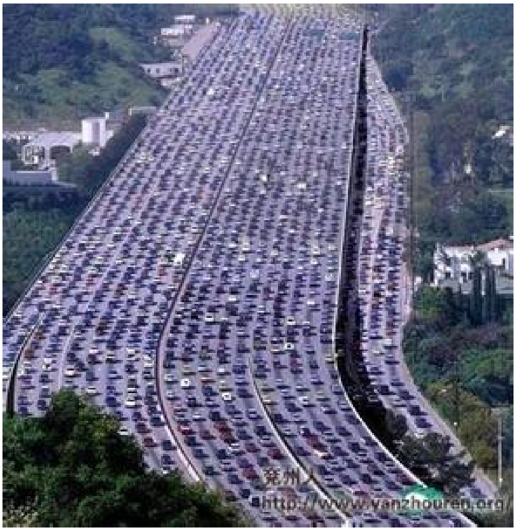

Figure 5. Traffic jam in Beijing

Figure 6. Severe haze in Beijing

In 80s to 90s of the last century one of very attractive a seismic technique was so-called active control of structures. It started from U.S and even full scale buildings were completed in Japan. Should we follow it closely? Most of Chinese scholars did not. They thought that even the active control is very advanced technique, if it is introduced in structural engineering, people have to face a huge mass and a large amount of energy consumption hardly be avoided. There is Chinese saying: “Soft words win hard hearts”, the father philosophy in China publicizes the spirit which also is away the rock with water. In this case most Chinese scholars prefer to choose passive control of structures. In another words, they prefer to take taijiquan, a kind of traditional Chinese shadow boxing, instead of western boxing. It is proved that the passive control of structures has become more acceptable (Liu and Ang, 2014).

4. TO BRIDGE THE GAP BETWEEN THE EAST AND THE WEST

In 21st century a large number of critical infrastructure projects are in developing countries, but advanced technology is in the developed countries. If there is no technical support from the west the progress of construction development in the east would be very limited. Also, if there is no practical projects available from the east the technical progress in the west would like “castles in the air”. In this case the international cooperation is very important necessary. In international cooperation if one side just keeps giving and another side only keeps accepting it certainly cannot last very long. It is very clear a sustainable international cooperation has to a win-win program.
During September and October of 2013, a new concept so-called “One Belt and One Road (OBAOR)” has been put forward by Chinese Government, which includes two concepts of "Silk Road Economic Belt" and "21st Century Maritime Silk Road"(Figure 7). In fact, OBAOR is not an entity and mechanism, but ideas and suggestions for cooperation and development.

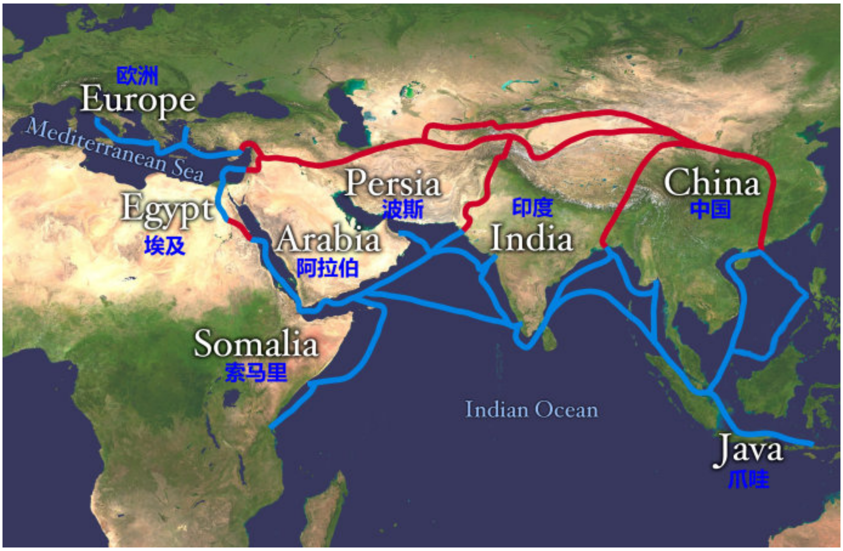

Figure 7. One Belt and One Road

“This visionary conception that leverages on China's historical connections has created a new opportunity to rejuvenate the economic and cultural ties built via the ancient SilkRoad”(2014-10-11 16:53:44; CRIENGLISH.com; Web Editor: Zhang). It presents a "win-win approach" to peaceful coexistence and mutual development. “The idea carries forward the spirit of the ancient Silk Road that was based on mutual trust, equality and mutual benefits, inclusiveness and mutual learning, and win-win cooperation.”The vision for “OBAOR” allows “the countries involved to create a three-dimensional and multi-layer transportation network that connects them via land, sea and air. That includes the New Eurasian Continental Bridge, which is regarded as the 'modern Silk Road', the China-Singapore Economic Corridor that runs through the Indo-China Peninsula and the Bangladesh-China-India-Myammar Economic Corridor that connects China to Southern Asia.”Once the "OBAOR”vision is realized, “it would create the most promising economic corridor, directly benefiting a population of 4.4 billion people or 63 percent of the global population, with a collective GDP of 2.1 trillion U.S. dollars that accounts for 29 percent of the world's wealth. The related region, which is the most dynamic and vibrant economically, encompasses many developing countries with emerging market economies and a big growth potential.”

For the past year, this concept has greatly helped promote China's cooperation with countries from Central Asia and Southeast Asia, in areas like trade and monetary cooperation, traffic connectivity and people-to-people exchanges. Along the northern Silk Road, as reported recently that (2014-06-25 22:07:55;CRIENGLISH.com;Web Editor: Ding Heng) “the cooperation has promoted rapid increase in trade volume between China and four central Asian countries of Kazakhstan, Turkmenistan, Uzbekistan and Kyrgyzstan. It jumped to 40.2 billion U.S. dollars in 2013, nearly 100 times than that of 1992. In the meantime, the revival of the Silk Road Economy has also helped improve infrastructure construction, create jobs and support local economies along the route.” Besides, “the Southern Silk Road has also proved important for China and South Asia, which are now home to nearly 2.8 billion people. Bilateral trade has increased to about 100 billion U.S. dollars in 2013; up from 35 billion U.S. dollars in 2006.”

As proposed by China in 2013, the Asian Infrastructure Investment Bank (AIIB) will be established soon, which is a multilateral development agency between governments to support infrastructure construction. The headquarter of AIIB is set in Beijing, authorized capital is around 100 billion American dollars. Until April 15th of 2015, in total, there are 57 countries would like to join it as original members.

Figure 8. Construction of Chao Tian Men Bridge in Chong Qing
(Main span 552m, completed in 2009)

Each country and region has their own development program considering their own condition (constraints and advantages) which should be respected. Certainly all the people have common interest. No matter from the West to the East, or from developed countries to developing countries, people have to make every effort to improve their own living condition , at the same time , people should also work together to ensure our common interest, which is the sustainable development of our whole world, which is so-called "Thinking in global and working at local". The reason is very simple, because people all only have one globe (Liu, 2004, 2006, and 2008).

4. REMARKS

China is one of the developing countries. As shown in Figure 8, which is an arch bridge with the longest span in the world, if it is imagined that the left half means developed countries and the right half means developing countries, China seems to be located around the incomplete arch top joint. It faces a gap from a developing country to a developed country. Chinese people deeply feel that there is our duty to bridge the gap. At first, as a member of the big world family, all of the Chinese engineers, technicians, and workers should certainly make every effort to bridge the gap, which means to contribute for the world for its sustainable development. The reason is very simple, because all of us only have one globe.

REFERENCES

Xila Liu and A. H-S.Ang, 2014. ASCE Council on Disaster Risk Management Monograph No.8, May 16-18 2014. Shanghai China（ISBN-13 978-0-7844-1347-0 9 780784 413470）

Xila Liu (the first principal draftsman), 2004.“2020: Research on the Development of Engineering Technology in China”, the China Association for Science & Technology (CAST), Beijing, China.

Xila Liu (Chair Scientist), 2006.“Annual Progressive Reports of Science and Technology in Civil Engineering”, China Civil Engineering Society, Beijing, China.

Xila Liu (Chair Scientist), 2008.“Annual Progressive Reports of Science and Technology in Civil Engineering”, China Civil Engineering Society, Beijing, China.

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Sustainability And Engineers
A Perspective To Future Generation And Society

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Abstract

During the past decades, societies have evolved tremendously in terms of lifestyles, needs, exploitation of resources, practices without limitations while at the same there are people on the planet who are missing the basic necessities to live with their dignities. These trends cannot be sustained indefinitely without depleting earth resources, placing at risk the life of future generations, polluting our environment and harming ourselves. Therefore, another way of thinking is required to allow our lives to be sustained. Consequently, all concerned parties (universities, industries, companies, societies, governments, etc...) should approach the problem and cooperate effectively in order to have sustainable societies. In this work, the issue is addressed mainly from the university perspective. That is, universities, particularly Engineering Faculties, should revisit their curricula in order to address the challenges that are faced when the issue of sustainability is incorporated. In other words, students should learn several crucial and vital principles to attain sustainability and some of these principles are introduced in this paper such as understanding the problem

and its impacts, critical thinking, ability to make sound decisions, communication with colleagues who are knowledgeable about the issue at different levels (such as environmental, economical, societal, technological).

1. Introduction

The issue of sustainable engineering was first addressed by the world commission of the United Nations on environment and development in its report during its plenary meeting that was held in December 1987 [1]. In that report, the term sustainable development is defined as "*a form of development that meets the needs of the present without compromising the ability of future generations to meet their own needs*". Also, it identifies the environment, the economy and the society as the three levels which are addressed by a sustainable approach. Others researchers have provided a similar definition which is defined as being a process that can lead to a balance between the environment issue, the social issue and the cultural issue [2]. This definition entails the fact that a compromise should be achieved between them. Consequently, the design of a system, a component or a process should not favor one issue over another.

The issue of sustainability and sustainable development have been gaining a big momentum over the past years. The universities are modifying, particularly, their engineering programs in order to include this component and to provide the needed skills and expertise which engineering students should acquire during the span of their university years. In this context, sustainability is an ABET (Accreditation Board for Engineering Technology) student outcome that engineering students should possess at the time of their graduations. It is clearly stated that the student should have "*an ability to design a system, component, or process to meet the desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturing and sustainability*" [3].Thus, it becomes clear that the activities and the actions that are taken by engineers to fulfill a set of specifications embed certain interdependence between the various factors.

The planet earth is not just to fulfill our needs and support our way of life. It was there in the past and it should remain for future generations. Humans currently take advantage of its vast resources (energy, water, sea, air, vegetation, animals, plants…). Humans are in great need of fresh air to breath. Therefore, they should not pollute the clean air by various damaging emissions that will result from cars, factories, electrical generation plants, motors etc..... For example, it is needless to say that currently the generation of electricity is mostly based on oil that is extracted from underneath i.e. under the land and the sea. Thus, a particular neighborhood will be polluted with particles that are hazardous to the life of the inhabitants by a source that is not a renewable form of energy. Besides, the source could be depleted and will not exist for future generations. The hazardous emission is not limited to a particular region i.e. a border does stop the movement of air from one region to another or from one country to another. Also, emitted particles will return to earth as acid rain that can damage greatly the forest sand all types of plants and vegetations. Subsequently, it may reach the wells underneath (particularly, drinking water) and will be dropped over the seas and its richness might be affected. Several issues are at stake from the point of view of sustainability. First, if the generation of electricity is achieved using a source of renewable energy such as the sun, the electricity is provided in a sustainable manner. The energy is provided without any pollution and consequently without any health hazard. Also, the environment will benefit from such approach and will be preserved to future generations. Besides, the approach entails a moral and an ethical issue to (at least) human beings i.e. health and the life's quality of the inhabitants. Therefore, this will stress the importance to modify the current laws and develop a new legal platform to encourage the use of such renewable energy. This will improve the economical status of the inhabitants, the region and the country on the long run because the electricity is generated without spending money on the purchase of oils. Needless to say, that the society (its inhabitants) by taking such sound decisions, will ripe great benefits for themselves and their children (health, economic,..). Also, this will encourage companies to develop such systems and to extend their use to other applications. This simple example highlights the fragility of our planet and its ecosystem, how all the various issues are interconnected and the importance to fulfill the needs of the current societies without compromising the needs of future generations. This also emphasizes the big challenges that are facing engineers in practicing sustainability.

2. Approach

The sustainable development, particularly in the engineering field, is mainly characterized by the activities and actions that are taken by engineers. However, this does not mean that the companies, industries or the people requesting the product are not responsible at all. Unlike the university, the industry is in the business to make profits which may lead to overcome the objectives of producing a sustainable product, design, project or process for the benefits of the society. Therefore, it should be highlighted that sustainable development is not mainly the responsibility only of engineers. The responsibility should cover all interested groups and societies.

In this context, the university should play its valuable role in order to prepare the new engineers to design systems (simple, complex…) according to given specifications requested by customers, employers and stakeholders without damaging the environment, depleting the natural resources and putting at risks the inhabitants. Even though, the objective is to satisfy the needs of the current societies, the student should be equipped with skills and abilities to provide a sustainable solution for future generations. They should have the ability to analyze the system and understand its economic impact, environment impact, cost impact, the risks involved, the long-term effect, the short term effect, the ability to minimize all negative effects and to maximize the benefits to the environment and to the societies.

2.1 Problem Understanding and Impacts

A vital step to provide a solution to a particular engineering problem (or any problem in a particular field and discipline) is to understand "very well” what is needed to be accomplished from all perspectives. That may lead to a solution in which certain activities, actions and/or tasks are implemented. However, the most important is to associate with the recommended decisions their effects and impacts (positive as well negative) on the societies at different levels (such as the health of the inhabitants, economical and so on) and the environment. Consequently, this understanding will help further the "designer" or the engineer to perform further improvement in order to minimize the negative effects and to maximize the positive effects under certain constraints which can be technological, social, etc... Besides, the engineer should look beyond the current days and provide a solution that is sustainable in the future. Furthermore, his vision should not be limited to his society. It should be extended to all societies around the globe. For example, assume that a product is manufactured and is satisfactory according to the rules and regulations of today. The product consists of a certain number of components which may deteriorate over time. Consequently, the environment and the health of people might be affected. Therefore, the dilemma becomes the following: can such product be manufactured even though the quality of inhabitants' lives will be at risk? Is it wise to design a system and/or to perform actions or activities that could lead to unsustainable development at the local, regional and/or global levels? Consequently, is it an objective and good practices to place more pressure on various depleted resources in order to create more environmental problems, to introduce more social problems, to induce more negative effects and to put at risk future generations?

Thus, this aspect is of great interest and value to universities, especially one of its objectives is the preparation of engineering students to be easily employed and to have successful professional lives. Besides, sustainability is an outcome required by accreditation agencies and professional societies. In his context, ABET requires sustainability for the accreditation of an engineering program i.e. *"the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental and societal context (outcome (h))" [3]*.

2.2 Critical Thinking

The university should equip the future engineers with the ability of critical thinking. It is among one of vital characteristics that help students to have a bright and successful carriers. Even it should be acquired before a student reaches the university i.e. during his high school years. In other words, engineers (among other capabilities) should be resourceful, innovated and have the ability to create and devise new solutions and new approaches to address the problem at hand. There is no unique solution to such problem in which sustainability is incorporated. The problem is not simple and is usually complex due to the interconnectivity between the various issue i.e. economical, health, technological, social, design, conception, environmental etc.... Students should not re-iterate what already exists i.e. provide an existing solution. Thus, this will emphasize the fact that the university should prepare students with the ability of problem solving, critical thinking and leadership. Besides, it is not enough for engineers to provide an acceptable solution and to satisfy all the involved parties. That is, the technology, the research, the knowledge and the information are evolving and are changing from one day to another at a fast pace. This change may lead tomorrow to a better solution. Also, engineers cannot predict the future performance of the selected solutions. Therefore, their design should be flexible enough to incorporate such changes and to embed easily the modifications into the recommended solutions. Needless to say, that the current solutions are provided based on the current state-of art technology, knowledge, information, tools, skills, expertise and resources which might be different in the days to come.

2.3 Compromise

As stated earlier, the problem is usually complex and the solution might not be at all trivial. To achieve sustainable development, several issues should be addressed simultaneously i.e. technologically, economically, environmentally, socially, availability of knowledge. Consequently, several solutions that fulfill the given specifications should be developed and presented and each solution is a compromise among all the stated issues. Then, the most appropriate solution will be selected. In other words, the developed solution should be balanced among these various issues. For example, can an engineer design a system such that all the various issues can be achieved with a 100 percent of satisfaction? If not, a compromise should be attained and consequently a balanced solution will be more appropriate. This factor can be elaborated as follows: if the current state of technology does not allow the development of a system (or a device) that does not purify water from all possible contaminations, does it mean that such system which purifies the maximum possible contaminations should not be devised even though the water is drinkable without any hazardous effects? If it is too expensive to be commercially available and consequently, cannot be afforded by the inhabitants by all inhabitants (cost), does it signify that the engineer should not build such filter so that it will available to municipalities? From these couple questions, it becomes clear that a compromise is in accordance. It should be highlighted that the solution should lead to certain gains in all aspects i.e. social environment, economic, heath, future, etc....The emphasis on the use of renewable resources is another example.

2.4 Team Work & Communication

Sustainable development requires that the involved parties have the abilities to take a sound and well-thought decisions from the various alternative solutions which are devised. As already stated, this will emphasize the fact that the problem should be well understood and its impacts/effects (Pros and Cons) on the various entities (such as societies, the environment and the economy) should be well defined so that the appropriate approaches that can yield a balanced and acceptable solutions are developed. Also, the legal framework in the country (if the problem is local) or in the countries (if the problem is regional or international) must be addressed i.e. the manufacturer of a particular product should be aware of the local laws or foreign laws governing the manufacturing and selling of such product locally, regionally or internationally. Therefore, a good and practical solution requires the effective involvement of the various actors in making sound decisions and choosing a solution that is sustainable i.e. the importance of the work in a team[4]. That is, a group of professionals (engineers, stakeholders, developer, designer, business marketing, system design, programmer, technical ...) should be created and should bring all their skills, knowledge and information to produce a sustainable product or process. Furthermore, each member of the group should be actively (not passively) participating in achieving the intended objective. Therefore, all members should discuss the given problem from different views and perspectives to identify the appropriate tools, approaches, knowledge and skills that are required to develop the sustainable solution.

The team consists of members and professionals from different disciplines and fields highlights the added value of communication. Therefore, the members are not all engineers and consequently, it is not anymore enough to speak the same "technological language”. They should have the ability to “listen” to each other and be receptive to the various point of views. That is, the communication is much more demanding than discussing an issue technically with a professional having the same background. Thus, the university should prepare engineers to acquire such skills namely; communication and team work, and to possess the ability to work in Multi-disciplinary settings. Besides, the team work and communication skills will lead to a better exchange of information and a better understanding of the interconnections among the various factors (such as, the economy, the technology, the environment, the society..) which are embedded in the design of a sustainable product or process to fulfill the required needs. Finally, it is needless to state that these skills are required by accreditation agencies and professional societies i.e. for example, ABET requires the student to acquire *«an ability to communicate effectively (outcome (g))"* and *" an ability to function on Multi-disciplinary team (outcome (d)) "***)** [3].

3. Conclusion

Today, sustainability and sustainable development are becoming a vital issue to be addressed by universities and to equip engineering students with the corresponding skills. It is increasingly becoming of great and valuable importance at the local, regional, and international levels. The sustainability requires the effective involvement and the active participation of all actors: engineers, universities, industries, governments, people and societies at large. The technical skills, tools and expertise which engineering students acquire are not enough to fulfill the needs of current societies and future generations. They should take into consideration other aspects such as environmental and social issues in their design, professional activities and actions. Thus, they should understand the problem under consideration and the corresponding positive and negative impacts in order to reach a compromised solution that will satisfy the current needs and keep the possibility for improvement or modifications in the coming future. They should be equipped with the knowledge and abilities to weight the various alternative solutions and to select the best decisions that minimize the risks to future generations.

References

[1] United Nations General Assembly Report of the World Commission on Environment and Development (42/187), 96th Plenary Meeting, 11 December, 1987.

[2]W. McDonough and M. Braugart, " Cradle to Cradle", North Point Press, New York, NY 2002.

[3] Accreditation Board for Engineering and Technology (ABET), "Criteria for Accrediting Engineering programs", 2005.

[4] Antoine B. Abche and Abdul M. Alameddine: ”Preparation of Engineers for a Sustainable Future in This Modern Era**”,** Journal of IDEAS, Number 17, pp. 39-47, 2012.

Achieving Sustainable Adaptive Reuse In Architectural Design Studio Using Environmental Simulation

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Abstract

Education for sustainability must go beyond teaching sustainable strategies in design methodologies. It must give students practical skills that enable them to continue learning after they graduate.

This paper addresses the integration of sustainable design process as a pedagogical approach in the architectural studio which is applied on an adaptive reuse project. It aims to explore the use of building simulation as a tool to evaluate different sustainable solutions, to highlight on the significance of design decisions and to emphasize on improving building *performance indicators. It also investigates Blooms taxonomy as a benchmark of student's learning domains, linking it to the environmental simulation in design Studio by developing this methodology of learning architectural design.*

An assessment of several projects carried out within design studio course using Design Builder; simulation software in the design process will be compared with the conventional design method that is based on functional and aesthetic criteria only. The challenge of limiting the design within the constraints of an existing building reveal that site selection impacts the sustainable approach through the design process.

The result shows the significance of this quantitative experiment that can support students in testing different alternatives from the early stage of the design process and manipulate their design based on informed and reliable results to optimize building performance.

Keywords: *adaptive reuse, design studio, simulation, sustainability, design builder*

1 Introduction

Over the past decades, the built environment is increasingly responsible for the deterioration of the natural environment. The depletion of energy, materials, waste and pollution dispersion are all problems that result not only from the construction phase but during the entire building life cycle and after demolition. Though there is an increase in awareness of global warming in different domains, sustainable policies are still weakly applied especially in the developing countries (1).

In response to that, the UN decade of Education for sustainability 2005 - 2014 launched a program which aims to ensure that all higher education establishments are integrating principles, and practices of sustainable development (2). Furthermore, in their second report UNESCO focused on processes and learning in the context of Education for Sustainable Development that have the potential to be catalysts for innovation in education(3). In relation to this, architectural schools like many higher educational institutions accord recently high priority to sustainability by integrating green concepts in their curricula..

However, academics are still facing lacks on how to bridge the gap between the theoretical knowledge and the application of environmental design. According to (Altomonte 2009), the formation of building practitioners needs to inaugurate amendments that support the successful achievement of awareness of environmental concerns in the practice of architecture. The study also highlighted that "University curricula have shown to be relatively ineffective in methodically integrating sustainable environmental design in the education of students of architecture" (4).

2 The Architectural Design Studio and the emergence of simulation tools

An architectural project is a result of complex interactions between different design parameters that should not only provide the comfort and well-being of the inhabitants of the internal space but should also minimize the impact of the building on the surrounding environment(5). The conventional teaching method in the design studio is concerned with the visual appearance of the mass and functional purpose. Even modern architects like Le Corbusier, Walter Gropius and Mies van der Rohe adopted “form follows function” as design principles(6). Nevertheless, architectural education should not be limited to physical building design but it should also integrate value system, sustainability and technologies. Limited by the conventional analytical tools, the traditional discipline neglected building performance concerns related to comfort, lighting, acoustics and other associated aspects. Hence, there was a disconnection between applying the design parameters and building sciences. As stated in (Papamichael K, Pal V 2002), "Design studios and building science courses have been conducted independent of each other, mainly due to a lack of tools that allow quick and easy consideration of building science criteria, such as comfort and energy requirements, during the design process". (7)
The emergence of simulation tools can integrate sustainable principles within the architectural education and accordingly link the theory with practice within the studio. A number of simulation programs have been ecently developed. The listed top rated free software capable of whole building simulation are “Energy Plus” and “Open Studio”(8). “Design Builder” is an “EnergyPlus” graphical user interface appropriate to inform design through performance based decisions. “EnergyPlus” is "a whole building energy simulation program that engineers, architects, and researchers use to model energy and water use in buildings."(9). “Energy plus” comprises "a core 3-D modeler and 9 modules which work together to provide in-depth analysis of energy use, consumption and commitment for any building" (10). It ensures that the designs meet performance targets early in the design process. It also enables compliance with the building rating systems requirements such as LEED, BREEAM.

2.1 Early integration of sustainability in the design process

Simulation tools not only facilitate decision making within the complexity of the design process but also engages students in multidisciplinary approaches. These methods are capable of broadening the knowledge of sustainable design as a multidimensional discipline encompassing many levels to be integrated in the design studio. On the other hand, building energy modeling could be an effective game based learning versus the traditional method(11). The incorporation of these methods within the design process have a potential to provide students an effective path to understand the principles of sustainability in a holistic manner and with measurable reliable results allowing a science based approach.

2.2 Using environmental simulation in relationships to Blooms taxonomy

The modeling procedure expands student's skills in association with different levels in the cognitive domain of Blooms taxonomy. The cognitive domain taxonomy (Blooms, 1956) classified by an educational committee is widely accepted in many fields and has been identified as, “arguably one of the most influential education monographs of the past half century.” In the table below, Bloom's domains (1956) are compared with Lukman (2013) and the new methodology of using simulation programs integrated within the design process. These additional skills are based on the observation of our students during their design process.

Additional Skills and Advantages of using Design Builder

Cognitive Domain (Blooms 1956)	**Learning in a "Conventional" Design Studio (Lukman 2013)**		**Design Process Using Simulation Software (Modeling Procedure)**
Knowledge *Level 1*	Knowing the design requirement	Comprehend the main goal to achieve the most sustainable design ←	- Theoretical Knowledge of building performance parameters - Adequate simulation software skills
Comprehension *Level 2*	Understanding the objective of the design requirements	Identifying the Parameters that can influence the building's performance ←	- Data Collection of the existing building (Base Case Scenario)
Application *Level 3*	Using the information to execute design or to solve the design problem	Application and comparison between several alternatives ←	- Input Parameters Modeling (Building the geometry) - Running the simulation
Analysis *Level 4*	Critical thinking: identifying/ analyzing the effectiveness of design components; making design decisions based on facts	Linking the theoretical modules to the design module ←	- Analysis of the Output Parameters
Synthesis *Level 5*	Proposing new and original design solutions without borrowing literally from precedents	Targeting the Performance Criteria: Energy Consumption, Day lighting, IAQ ←	- Visualizations of Results - Interpretations of Results
Evaluation *Level 6*	Evaluating the merit of the proposed design solution	Quantitative evaluation rather than purely aesthetic and functional needs ← Compliances with building rating systems	- Selecting the optimum Solution

Table 1 Additional learning skills that Design Builder can add to the Blooms Taxonomy based on the conducted project relative to the conventional Design Studio

3 Methodology

3.1 Adaptive reuse as a challenging context

In a study on research design education for adaptive reuse, (Eyüce, 2010) discussed that "Context concerns itself not only with relationships between built forms, natural and manmade environment but also expands over a vast area of interpretations ranging from a simple single feature to such interrelated conditions like social, cultural, economic, and environmental factors" (14).Adaptive reuse of an existing building refers to the process of reusing an old site or building for a purpose other than which it was built or designed for.

Students at Beirut Arab University (BAU), faculty of Architectural Engineering were assigned a design project as a group work of 4 to 6 students during the spring semester 2014-2015. This opportunity to work as a team was challenging but valuable in terms of interaction engagement between the students. Each group is required to select an abandoned building in Lebanon so that multiple options are addressed and thus different responses will be taken. The aim is to reuse an old neglected building through an eco-friendly approach and creative solutions. It therefore decreases the consumption of materials and reduces the impact of Building life-cycle by improving the environmental and economic performances. Adaptive reuse is considered as part of the known sustainable strategies. In LEED v4 for Neighborhood Development, two credits can be earned with the building reuse and adaptive reuse. The requirement is to "Incorporate into the project the reuse of one building that maintains at least 50% (based on surface area) of the existing building structure (including structural floor and roof decking) and envelope (including exterior skin and framing, and excluding window assemblies and non-structural roofing material)." (15) The simulation strategy in this project was done as a process of the adaptive reuse of the old building to make it functional for the new use, hence the methodology integrated the simulation tools as a part of the adaptive reuse.

3.2 The simulation tool: Design builder

A comparison between different simulation programs and graphical interfaces using Energy Plus such as COMFEN, Design Builder, DIVA for Rhino, Open Studio and Simergy(16) shows that they are all similar in description however Design Builder is easy to learn and is considered as a standalone software that can integrate CFD and radiance day lighting simulation. The selection of this software as a tool in this design project was also based on its user friendly interface in addition to its precision. It also allows designers to evaluate energy efficiency and carbon performance during early stage design. It enables the visualization of solar shading and the comparison of alternatives to maximize comfort, day lighting and natural ventilation. It also helps students in quantitative evaluation of various designs in order to assess the impact of design parameters on building performance and to identify the ultimate solution.

4 Analysis and Synthesis

Students are required to apply their theoretical knowledge and simulation skills into practice. On the basis of taken lectures during the semester, students should have attained an adequate knowledge of how several parameters can influence the building's performance including; building orientation, window opening area, glazing type, shading devices and its positions. The design parameters evaluated emphasized that each building design has its own context which dictates the design. This indicates that implementing any solution must be based on quantitative analysis and on a simulation process. For example, in the early decisions, the additional blocks should be based on using the simulation software as a tool to investigate the effectiveness for the optimum design solutions of comfortable and energy efficient buildings. It is important to specify certain questions and conditional statements in order to support the finally reached results. Assessment of performance includes several design parameters such as designing shading devices, orientation and therefore cooling load reductions to reach comfort zones. Once having applied the previous criteria, students become able to develop the critical thinking by considering the simulation process as a vital part of evaluating the new building design in comparison with the initial condition as a part of the adaptive reuse project.

In their design project, students specify the geographical location during the modeling procedure and accordingly the weather conditions (temperature, humidity, wind speed) of the region are used for simulation.

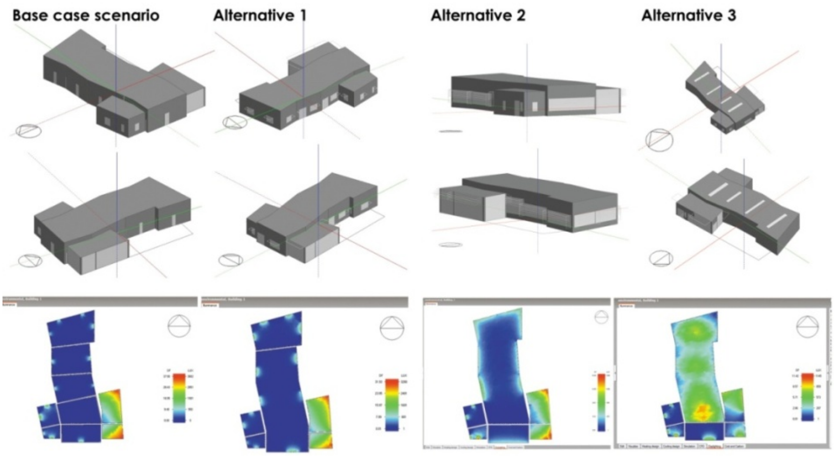
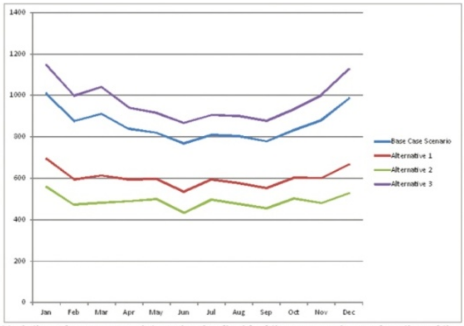


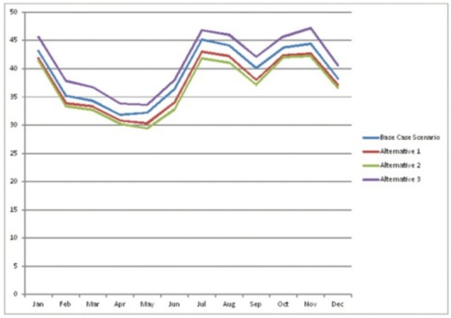
Figure 1. Different scenarios and day lighting according to different wall to window ratio.

	Wall to window ratio	Glazing	Shading	Cooling Loads(July)	Daylighting	Cost
Base Case Scenario	-6% openings -100% openings	Single Clr6mm	-Local shading, 1m overhang	65.9 KW	Min: 0.000 lux Ave:3.645 lux Max:37.967lux	627,772 U.S.D
Alternative1	-10% openings -100% openings	Double LoE Clr6mm/13mm Arg	-Local shading, 1m overhang	60.27 KW	Min: 0.016 lux Ave:3.472 lux Max:32.735 lux	620,259 U.S.D
Alternative2	-40% openings (-100% openings -5% 10%	Triple LoE Clr3mm/13mm Arg	-Louvres 1m projection + 1m overhang & sidefins -Louvres1.5m projection -Window shading	58 KW	Min: 0.007 lux Ave:2.416 lux Max:16.872 lux	635,704 U.S.D
Alternative3	-0% wall openings -70% openings	Double LoE Tint 6mm/13mm Arg	-4 skylights -Local shading, 2m overhang	57.05KW	Min: 0.007 lux Ave: 3.831lux Max:11.428 lux	620,363 U.S.D

Table 2 Parameters variations for alternatives and analysis of results.



Variation of occupancy internal gains (kwh) of the proposals as a function of time (months)



Variation of humidity (%) in the proposals as a function of time (months)

Figure 2 Numerical Comparison between different alternatives in terms of internal gains (Kwh) and humidity (%).

After completing the project, a questionnaire was circulated to the majority of students in this course to evaluate their feedback on the first experience with this methodology in design (appendix 1). After reviewing the results of the questionnaire and summarizing them, we found out that conducting the design processing simulation software in the design process was rated between quiet easy and reasonable in the level of difficulty of each phase in the modeling procedure compared to the conventional methodology of design in addition to being so helpful in measuring the building sustainable performance discussed previously which improved their design development in achieving a more sustainable architecture, despite the occurrence of some technical challenges regarding the usage of the proposed software. And as a final comment the students were eager to explore more software packages in the domain of sustainable simulation.

Figure 3 Students feedback on Modeling Procedure through Design Builder

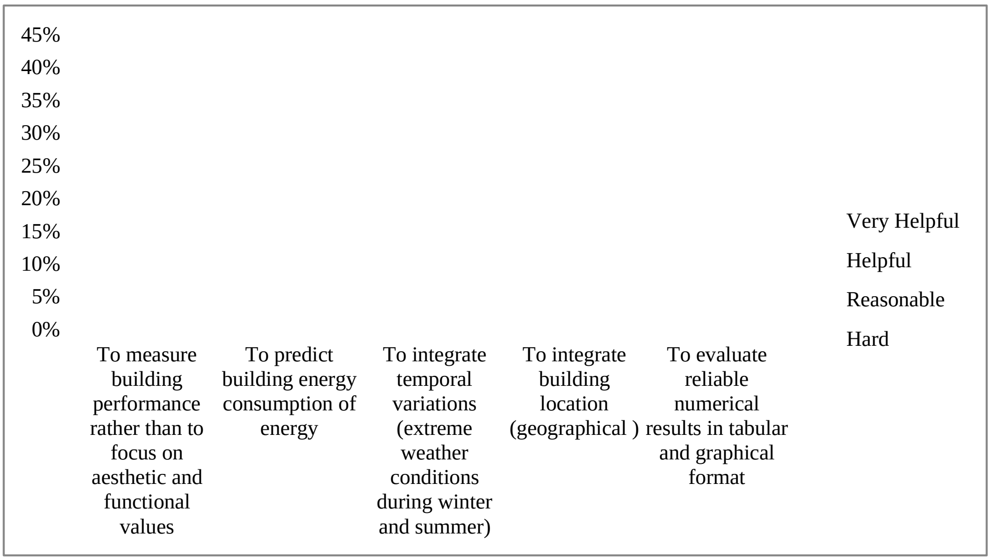


Figure 4 Design Builder compared with the conventional methodology of design

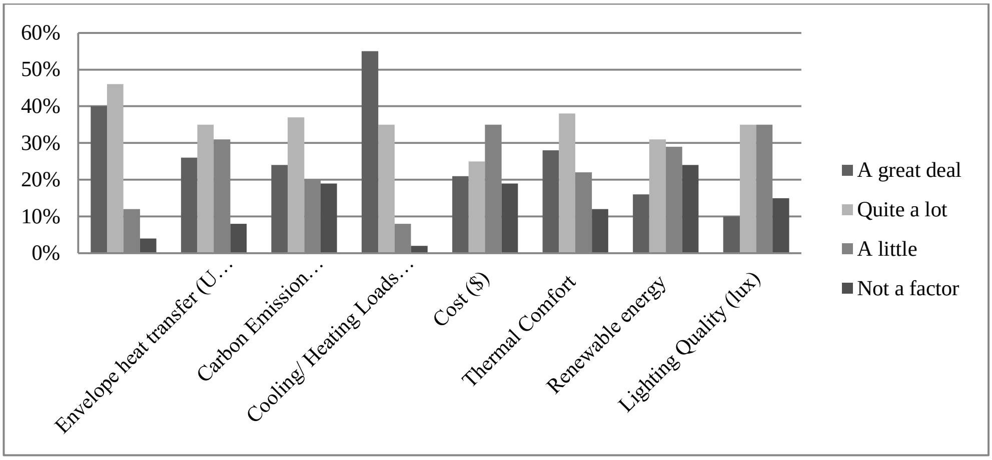


Figure 5 Performing indicators contribution to the final design decision

5 - Conclusion

This exercise aimed at effectively employing quantitative methods in analysis as a part of the adaptive reuse projects and to be a base for further studies in the field. It encourages the integration of building energy simulation in the design process. This simulation tool in calculating the whole building energy simulation measures expected energy use based on the building's geometry, climate, building type, envelope properties, and active systems.

The importance of the combination of the core modules in the design studio is essential to understand sustainable theoretical lectures and simulation application tools. The evaluation of different alternatives facilitates the design decisions in a science based approach. More training and explanation for students should be given on the reading of technical data visualization, running the simulation, and evaluating the design alternatives. Further investigation of other simulation software is necessary in order to recommend the most suitable one for architects.

6 --References

1. Hannula E-L. Going Green: A Handbook of Sustainable Housing Practices in Developing Countries. UN-HABITAT; 2012. 124 p.

2. Sector UE. United Nations Decade of Education for Sustainable Development (2005-2014): International Implementation Scheme. U N Educ Sci Cult Organ UNESCO Paris Fr. 2005;
3. UNESCO 2012. Shaping the Education of Tomorrow: 2012 Report on the UN Decade of Education for Sustainable Development, Abridged [Internet]. Available from: https://sustainabledevelopment.un.org/content/documents/919unesco1.pdf
4. Altomonte S. Environmental Education for Sustainable Architecture. Rev Eur Stud. 2009;1(2):p12.
5. Keeler M, Burke B. Fundamentals of Integrated Design for Sustainable Building. John Wiley & Sons; 2013. 358 p.
6. Does Form Follow Function? – Smashing Magazine [Internet]. [cited 2015 Jul 23]. Available from: http://www.smashingmagazine.com/2010/03/does-form-follow-function/
7. Papamichael K, Pal V. Bridging the gap between building science and design studios. Lawrence Berkeley Natl Lab [Internet]. 2002 [cited 2015 Jul 13]; Available from: http://escholarship.org/uc/item/7g74x44f.pdf
8. Softwares Listing | Best Directory [Internet]. [cited 2015 Jul 23]. Available from: http://www.buildingenergysoftwaretools.com/software-listing?combine=&field_catagory_tid%5B%5D=201&field_platform_tid=4&field_price_tid=All&field_last_updated_value%5Bvalue%5D%5Byear%5D=2010&field_language_tid=All&sort_by=field_rating_rating&items_per_page=40
9. http://apps1.eere.energy.gov/buildings/energyplus/ - Google Search [Internet]. [cited 2015 Jul 24]. Available from: https://www.google.com/search?q=US+Department+of+Energy.+2013&ie=utf-8&oe=utf-8#q=http:%2F%2Fapps1.eere.energy.gov%2Fbuildings%2Fenergyplus%2F
10. DesignBuilder - building simulation made easy - DesignBuilder - Simulation Made Easy [Internet]. [cited 2015 Jul 23]. Available from: http://designbuilder.co.uk/
11. Reinhart, Christoph F., Timur Dogan, Diego Ibarra, and Holly Wasilowski Samuelson. Learning by playing–teaching energy simulation as a game. J Build Perform Simul 5. 2012;6:359–68.
12. Saliklis E, Arens R, Hanus J. AC 2009-2: TEACHING ARCHITECTS AND ENGINEERS: UP AND DOWN THE TAXONOMY. 2009 [cited 2015 Jul 18]; Available from: http://content-calpoly-edu.s3.amazonaws.com/arce/1/documents/2_TEACHING_ARCHITECTS_AND_ENGINEERS__UP_AN.pdf

13. Ibrahim NLN, Utaberta N. Learning in Architecture Design Studio. Procedia - Soc Behav Sci. 2012 Oct 17;60:30–5.
14. Eyüce Ö, Eyüce A. Design education for adaptive reuse. ArchNet-IJAR [Internet]. 2010 [cited 2015 Jul 13];4. Available from: http://www.academia.edu/download/30363437/4.2-3.30-o._eyuce_and_a._eyuce_-pp_419-428.pdf
15. Building reuse and adaptive reuse | U.S. Green Building Council [Internet]. [cited 2015 Jul 24]. Available from: http://www.usgbc.org/credits/neighborhood-development/v10-pilot/gctc4
16. EnergyPlus - Bembook [Internet]. [cited 2015 Jul 24]. Available from: http://www.bembook.ibpsa.us/index.php?title=EnergyPlus

Appendix 1

Questionnaire on the use of Building Energy Simulation Software in the Design Process

This survey is designated to assess students' feedback on the use of building simulation as a tool during the architectural design education.

We would be very grateful if you could complete the enclosed questionnaire. Your response will be combined with other students to form an overall picture, so please respond only if you have taken **ARCH 339 - Environmental Design Course Spring Semester 2014/2015.**

1. Please indicate your level at the faculty of architectural engineering for the Spring Semester 2014/2015 (double click on the box and select checked).

Level Two ☐1 Level Three ☐2 Level Four ☐3 Level Five ☐4
March ☐5

2. During the design process, how would you rate the difficulty of each phase in the modelling procedure? **Please tick one box on each line (double click on the box and select checked).**

	Too easy	Quite Easy	Reasonable	Hard
Base case scenario (Data Collection)	☐1	☐2	☐3	☐4
Input Parameters	☐1	☐2	☐3	☐4
Modeling (Building the geometry)	☐1	☐2	☐3	☐4
Running the simulation	☐1	☐2	☐3	☐4
Analysis of the Output Parameters	☐1	☐2	☐3	☐4
Visualizations of Results	☐1	☐2	☐3	☐4
Interpretations of Results	☐1	☐2	☐3	☐4
Design recommendations	☐1	☐2	☐3	☐4

3. Compared with the conventional methodology of design, please indicate how helpful was using simulation software in the design process

	Very Helpful	Helpful	Neutral	Not very Helpful
To measure building performance rather than to focus only on aesthetic and functional values	☐1	☐2	☐3	☐4
To predict the use of energy from the building	☐1	☐2	☐3	☐4
To integrate temporal variations (extreme weather conditions during winter and summer)	☐1	☐2	☐3	☐4
To integrate building location (geographical)	☐1	☐2	☐3	☐4
To evaluate reliable numerical results in tabular and graphical format	☐1	☐2	☐3	☐4
To identify and prioritize alternatives to optimize the design	☐1	☐2	☐3	☐4

4. How would you rate the difficulties of Design Builder in the design process?

	Strongly Agree	Agree	Disagree	Strongly Disagree
Is easy to learn (user interface)	☐1	☐2	☐3	☐4

Has limits in Modeling complicated geometrical shape	☐1	☐2	☐3	☐4
Demand high specification for computer	☐1	☐2	☐3	☐4
Compatible with other software (Sketchup, CAD..) to export and import files	☐1	☐2	☐3	☐4

5. Selecting an adaptive reuse building support the concept of sustainability in you project

	Strongly Agree	Agree	Disagree	Strongly Disagree
	☐1	☐2	☐3	☐4

6. In your project, evaluate how much you would say each of the following performing indicators contributed to your final design decision.

	A great deal	Quite a lot	A little	Not afactor
Energy Consumption (KW/m2/year)	☐1	☐2	☐3	☐4
Envelope heat transfer (U value)	☐1	☐2	☐3	☐4
Carbon Emission (kgCO2/year)	☐1	☐2	☐3	☐4
Cooling/ Heating Loads (BTU)	☐1	☐2	☐3	☐4
Cost ($)	☐1	☐2	☐3	☐4
Thermal Comfort	☐1	☐2	☐3	☐4
Renewable energy	☐1	☐2	☐3	☐4
Lighting Quality (lux)	☐1	☐2	☐3	☐4

7. In your opinion, gaining new skills is essential in Education for professional practice?

	Strongly Agree	Agree	Disagree	Strongly Disagree
	☐ 1	☐ 2	☐ 3	☐ 4

8. Is there any other issue related to the use of building simulation in the design process on which you would like to comment? Please feel free to comment.

Sustainability In Civil Engineering Education

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Dr. Nariman Khalil is an associate professor in the department of civil engineering at the University of Balamand. She received her Ph.D. degree in reinforced concrete structures from the University of Leeds- England in 1991. She has more than two decades experience in teaching structural analysis and reinforced concrete design and providing consultancy for private and governmental sectors in the Middle East. Her technical publications in refereed journals and peer-reviewed conferences span multiple areas and disciplines including structural stability and design, concrete technology and high way materials. Dr. Khalil also excelled in national and international activities and is consistently involved in the organizing and chairing international scientific conferences. She is a member of several professional organizations such as the American Society of Civil Engineers (ASCE) & the American Concrete Institute (ACI) and currently serving as a Board member in the Middle East Society of Asphalt Technologists (MESAT).

Abstract

Throughout history, civil engineers have contributed enormously to the development of society and to the huge improvements in the standards of living. Their activities have certainly made some negative impacts on the surrounding environment, society and affected natural resources preservations. Civil engineers, being part of the problem can also be part of the solution, by contributing to sustainable development and green design issues. They have faced many challenges in the past and this is another challenge they have to address. There are many approaches that will help the civil engineers of tomorrow be the leaders of sustainability efforts. This paper focuses on the role of, and need for, universities to create and promote a holistic approach in engineering education. The role of professional societies, as a key part of developing sustainability literacy among future engineers, is also addressed. The paper also looks at local *challenges and efforts in the country of Lebanon to promote awareness of sustainability development. Recommendations are made on embedding sustainability principles in civil engineering programs.*

Keywords: *Sustainability, Education, Civil Engineering, Programs*

1. Introduction: Sustainability Defined.

In 1972, one hundred and thirteen countries gathered at the United Nations conference on the *"Human Environment"* in Stockholm, Sweden [1]. The conference was the start of global efforts aiming to address environmental problems. In 1983, United Nations appointed the Bruntland Commission charged with addressing the growing concerns about the accelerating deterioration of the human environment and natural resources and its consequences on economic and social development. The Report of the Bruntland Commission *"Our Common Future"* was published in 1987. It included the following definition of sustainability: *"Sustainability is the state of the global system, which includes environmental, social and economic subsystems, in which the needs of the present are met without compromising the ability of future generations to meet their own needs"*. The report suggested that international governments should meet to look at how to best reduce the impact of human activities on the surrounding environment for the welfare of future generations. These basic efforts led to other meetings and conferences, most importantly was the first Earth Summit, held in Rio, Brazil in 1992 and Kyoto conference (1997); where the issue of global warming and emissions of gases were discussed. Ten years later, a conference in Johannesburg met to review progress towards sustainable development. Other meetings were held to discuss the climate changes in 2007 and 2009. Several tools have been developed to assess and mitigate the impacts of human actions on the environment, such as Environment Impact Assessment (EIA) and Strategic Environmental Assessment (SEA). Both tools are reactive measures while sustainable construction is a proactive approach [1].

The most appropriate definition of civil engineering is Tredgold's [2] definition which is *"Civil engineering is the art of directing the great sources of power in nature for the use and convenience of man"*. The relation between sustainability development and civil engineering is hence obvious and this implies that the civil engineers are key factor in sustainable development and are decision makers about how to best use natural resources: material, energy, water…etc. An argument could be poised on whether civil engineers are ready to lead in sustainability efforts. Are they committed to implement required measures in their projects? Do future engineers acquire the necessary knowledge that helps them face the current challenges?

This paper suggests some solutions to improve the role of civil engineers in sustainability by developing a new approach to civil engineering education; fostering the importance of and identification of leadership and role models; promoting a shift in local policy and education programs for civil engineers in particular and engineering in general.

2. How can sustainability be achieved?

Previous researchers [1, 3, 4, 5, 6] have highlighted many guiding principles for achieving sustainability as a process in which our planet can be well-preserved. From the perspective of civil engineering as a profession, there are many challenges: the first is how to make choosing the sustainability option easier and cheaper for clients and contractors; then there is how to build the capacity of teachers and trainers to integrate sustainability into courses, how to make specifying for sustainability criteria in materials and processes an effective tool for change and finally how to embed sustainability thinking and practices into the culture of organizations and across different professional groupings. This paper will focus on the roles of universities and professional societies.

2.1 Role of Universities

Sustainability should have a well-defined identity of its own, with a solid scientific basis and significant perspective for growth. Major academic institutions offer graduate programs that focus on this very broad subject. However, regardless of the fact that single institutions have developed and implemented their own know-how, it is important to have a constant exchange of information and experiences in international conferences and symposia. In the inquiry report of the 21st Century Engineer [3], a group of young engineers conducted a survey targeting universities and colleges in UK. Their findings were summarized in the form of top ten recommendations related to leadership, universities, government and planners as far as sustainability is concerned. Here is the part of their results that is related to education:

- *Sustainable development was only a first degree third year or postgraduate option.*

- *The subject was an optional, rather than a mandatory module or course.*
- *Sustainable development was not integrated into engineering courses as a whole.*
- *Audit procedures for assessing the standard of the sustainable development modules or courses were weak.*
- *There was general apathy and lack of awareness concerning the value of introducing sustainability into engineering courses, amongst teaching staff and students.*

Though these findings may apply to many universities, suggesting that more plans are desperately needed in programs, it is quiet certain that the majority did not yet play their role in sustainability development. As a starting step the university can make plans for staff training by offering lectures that enhance their understanding of sustainability development. They can benefit from the Visiting Professor schemes who can advise on the inclusion of sustainability concepts in teaching and also on structure and staff skills. Revision of undergraduate and postgraduate programs is a major step to incorporate sustainability concepts and drive critical thinking among engineering students. Some examples can be quoted here:

Imperial College experience

At the Imperial College - London, a Centre for Doctoral Training (CDT) in Sustainable Civil Engineering was established. The Centre produces civil engineering doctoral graduates with interdisciplinary skills and research experience to contribute to multi-faceted and complex infrastructure projects, with training delivered through highly innovative industry-linked research. CDT adopts the widest possible definition of sustainability, covering the effective whole life design and performance of major civil engineering infrastructure. The Centre addresses key engineering challenges of: fit for purpose, economic viability, environmental impact, resilience, infrastructure inter-dependence and durability. It also considers the impacts of changes in population, urbanization, available natural resources, technology and societal expectations. This requires a broad-based approach to research training, effectively integrated across the wide range of civil engineering disciplines. Very few academic institutions are capable of providing in-depth training across this range of subjects. However, the Civil and Environmental Engineering Department at Imperial College, recently ranked number one in the world against its competitor departments (QS 2013), is uniquely placed within the UK to achieve exactly this. The Centre offers a Grand Challenge Project to address a major problem for the nation. Examples of 2015-16 Grand Challenge Projects:

- Multiple Use Infrastructure
- Low Carbon Civil Engineering
- Urban Resilience

The example of Imperial College can be thought of as an option for universities that offer doctoral degrees. The type of projects presented will of course vary depending on local needs. In the country of Lebanon, civil engineers face the challenge of limited natural resources. Considering reinforced concrete construction as an example, there is a huge consumption of natural aggregates. The number of allowable quarries is only sixteen according to the Ministry of Environment, while the estimated number of existing quarries is about one thousandendangering the whole country environment.Studies showed that quarries can annually reduce an estimated surrounding lands value by anywhere from 16 to 71%. Therefore, there is an urgent need to face such challenges and future engineers must be prepared and educated accordingly.

Strath Clyde University

Strath clyde University established a working group to decide how sustainability could be introduced into both under and post graduate engineering studies and into further academic research.

University of Balamand

University of Balamand offers graduate course on Sustainability and Green Buildings as an elective course for forth year students. The University also offers Master of Science in civil engineering – Environmental option in which many electives are offered dealing with issues related to pollution and waste management. Some research projects leading to Master degree or Ph.D. degree focuses on innovative issues related to concrete and asphalt technology and on the industrial processes that contribute to extensive energy use and pollution. Examples of such topics are:

- *"Recycled concrete as coarse aggregates for structural concrete production"*
- *"Improvement of asphalt for aging by using crumb rubber tires"*.

Based on the above, it sounds like a sensible starting point wherein each university forms a task group whose duty is to identify possible ways of incorporating sustainability and green solutions into offered courses at undergraduate and post-graduate levels.

Civil engineers' understanding of sustainability requires them to have knowledge in biological and social sciences. They do not need not to be experts in other professions but rather be able to be good team members.

Another way of integrating sustainability into education is to make course accreditation dependent on the inclusion of sustainability in teaching and marking. The ministry of higher education should formulate measures to assess the knowledge of sustainability as a prerequisite to issuing any license to be given to an engineering institution.

2.2 Role of Professional Societies

Professional engineering societies provide guidance, resources, Codes of practice and programs for engineers in order to improve the practice of the profession. Hence, they can help engineers to lead as sustainable and innovative problem solvers. The American Society of Civil Engineers (ASCE), for example has formally recognized civil engineers' obligation to practice sustainability by making it part of its Code of Ethics [7]. It also demonstrates its commitment to sustainable practice through public policy statements, technical codes and standards and contributes to organizations such as World Federation of Engineering Organizations.

ASCE defines sustainability as: *A set of environmental, economic and social conditions in which all of society has the capacity and opportunity to maintain and improve its quality of life indefinitely without degrading the quantity, quality or availability of natural, economic, and social resources.*

The same policy statement further states that civil engineers will "have a significant role in planning, designing, building and maintaining a sustainable future. *Engineers provide the bridge between science and technology. In this role, engineers must participate in interdisciplinary teams with ecologists, economists, sociologists and professionals from other disciplines, in applying technology to issues and challenges that require environmentally sustainable strategies and solutions" (ASCE 2001) [7].*

US Green Building Council (USGBC) has developed a Green Building Rating System known as <u>L</u>eadership in <u>E</u>nergy and <u>E</u>nvironmental <u>D</u>esign, LEED certification. LEED provides independent, third-party verification that building project meet the highest green building and performance *measures. There is a checklist which ensures that all aspects of sustainability are covered in the design and implementation of the project. USBGC has published two guiding documents [8, 9] and made them available for professors threading sustainability into their courses.*

The above statements serve as examples of what professional societies' responsibilities may include towards their role in bridging the gap that may exist between engineers and arising needs and help them face new challenges.

3. *Conclusions and Recommendations*

Based on the above discussion, the following remarks can be concluded and recommended for application:

- Civil engineering students need to be taught to consider the limited resources constraints, learn how to evaluate alternative resources, recycling and understand global sustainability.
- Changes are recommended to curricula and program content and context to teach undergraduates the complexity of sustainability. In particular, the civil engineering curriculum should incorporate sustainability and green design courses and promote problem solving thinking.
- Policy on accreditation of professional engineering programs should include the following two generic attributes: "*Understanding of the social, cultural, global and environmental responsibilities of the professional engineer*" and "*Understanding of the principles of sustainable design and development*".
- Government should include incentives for sustainability, green building design projects and implement taxes on landfills and construction waste disposal.
- *Orders of engineers are invited to clear their positions on sustainability.* New publications on this issue are called for. This may include an annual report on "*state of the Profession's Contribution to Sustainable Development*". Engineers and contractors must be more engaged with sustainability concepts through workshops, conferences, training...
- Value Engineering techniques should be used to look beyond the technical challenge to ethical and value issues [3].

4. *References*

[1] Ratnayake, N., "Sustainable Civil Engineering: Construction without destruction", University of Moratuwa, Sri Lanka, 2014.
[2] Paul W. Jowitt, "Systems and sustainability: sustainable development, civil engineering and formation of civil engineer", Proceedings of the institution of civil engineers, Engineering Sustainability" 157, 2004, issue ES P 1-11, paper 13854.
[3] The Engineer of the 21st Century Inquiry: Change Challenges for Sustainability", Forum for the future, 2003, UK, www.forumforthe future.org.uk.
[4] Trever M Daniell and Holger R. Maier, "Embedding sustainability in civil and environmental engineering courses", Proceedings of the 2005 ASEE/AaeE 4th Global Colloquium on Engineering Education, Australasian Association for Engineering Education. Paper 49.
[5] M. Bilec, R. Ries and H. S. Matthews, "Sustainable development and green design- who is leading the green initiative?"Journal of professional Issues in engineering education and practice, ASCE/October 2007.
[6] Jeremy D. Rogers, "Sustainability and Civil Engineering", Ohio Valley Regional Student Conference, paper 2, 2009.
[7] American Society of Civil Engineers (ASCE), 1996. Code of ethics, Adopted September 2, 1914 and most recently amended November 10, 1996.
[8] Andrea J. Schokker, "The sustainability concrete guide applications", U.S. Green Concrete Council, 2010.
[9] Andrea J. Schokker, "The sustainable concrete guide: strategies and examples", U.S. Green Concrete Council, 2010.

Thinking Globally, Acting Locally: Efforts Towards Immersion Of Sustainability In Civil Engineering Education

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Abstract

Over the past several decades, there has been an increasingly urgent call for attention to the importance of sustainability and sustainable development and for action to effect change. The American Society of Civil Engineers (ASCE) has been among the front-runners in promoting sustainable development in both engineering education and practice. This paper presents a description of ASCE's efforts towards incorporating principles of sustainability into civil engineering. It presents background on the inclusion of sustainability in learning outcomes and a discussion of approaches to incorporating sustainability in civil engineering curricula. It then reports the results of a survey of faculty members, administrators, and other stakeholders who participated in an ASCE webinar on strategies for incorporating sustainability into civil engineering curricula. The survey was designed to gage faculty interest in sustainability and their ideas and needs for resources to facilitate integration of sustainability into civil engineering curricula. It concludes with recommendations for next steps toward propagating curricular resources for civil engineering programs.

Keywords*: Sustainability, Curriculum, Modules, ABET, Civil Engineering Education, ASCE BOK2, Sustainable Development*

1. Introduction

1.1 A Global Call to Action

Charles Vest stated the case for sustainable development with a level of urgency greater than that of homeland security.

> I referred to homeland security as the Mother of All Systems Problems, but there is an even greater, and ultimately more important systems problem - that is the "sustainable development" of human societies on this system of ultimate complexity and fragility we call Earth. In Europe, sustainable development is part of everyday work of industry and politicians and a common element in political rhetoric - and rhetoric is a start. I am troubled that sustainable development is not even on the

radar screen in the United States… Nevertheless, sustainable development must be on our agenda as we prepare the engineers of 2020. [1]

The call to action towards sustainability and sustainable development is not new. Over the past four decades, the United Nations (UN) has convened stakeholders, set agendas, and implemented numerous strategies around sustainability and sustainable development. One of the most recent actions was the 2015 publication *Transforming Our World: The 2030 Agenda for Sustainable Development*, which describes a 15-year plan for achieving 17 sustainable development goals (SDGs) across the three pillars of sustainability - people, planet, and prosperity. The SDGs include areas commonly associated with sustainability such as clean water and sanitation, affordable and clean energy, and sustainable cities and communities. They also include challenges that are not commonly viewed as being associated with sustainability such as no poverty, gender equality, and reduced inequalities. The agenda describes several specific, measurable, aspirational outcomes for each goal and strategies for their attainment in a way that engages numerous stakeholders across multiple dimensions (policy makers, society at large, financial institutions, scientific community, etc.) to achieve global impacts by implementing actions targeting intra governmental priorities that support the 17 goals. [2]

As innovators, engineers must be leaders in the revolutionary change that is needed to achieve the SDGs. Engineering practice must make drastic strides away from the traditional business model to focus holistically on the triple bottom line. In order to achieve that, policies and policy making must rapidly evolve so that engineers' ingenuity and ability to effect change are not stifled. Of equal importance is the transformation of engineering education in a manner that ensures the preparation of graduates who will be highly capable of solving the complex problems that lie ahead of them.

1.2 The Civil Engineering Response

Because civil engineers play critical roles in society by creating infrastructure, controlling pollutant discharges, and developing communities, the American Society of Civil Engineers (ASCE) has been among the front-runners in promoting sustainable development practices. In 1996, ASCE identified sustainability as one of three strategic initiatives. The ASCE Committee on Sustainability (COS) was created with the charge to "direct, oversee, and coordinate the Society's implementation of ASCE's Sustainability strategic initiative." [3] The Board of Direction modified the

Society's Code of Ethics to include complying with principles of sustainable development as an ethical obligation. [4] Several ASCE policy statements (e.g. PS 418, PS 517, PS 299, PS 493, etc.) further establish the priority that the civil engineering profession gives to sustainability and sustainable development. [5] Additionally, in 2009 ASCE published *Achieving the Vision for Civil Engineering in 2025: A Roadmap for the Profession*, which describes civil engineers' roles as "master (1) planners, designers, and builders; (2) stewards of the natural environment; (3) innovators and integrators of technology; (4) managers of risk; and (5) leaders in shaping public policy…" to "…help achieve a sustainable world and raise the global quality of life."[6]

This paper presents a description of ASCE's efforts, primarily through the COS and its Subcommittee on Formal Engineering Education (FEE), towards infusing civil engineering curricula with sustainability so that future engineers are prepared and equipped to respond to local needs and contribute to the global call to action towards sustainable human societies. It begins with a discussion of outcomes and approaches to incorporating sustainability into civil engineering curricula. The paper then describes the results of a survey that was administered after an informational webinar to gage faculty members' and administrators' interest in sustainability, needs for sustainability-related curricular materials, and perspectives on sustainability in the curriculum. It concludes with recommendations for the FEE to consider as it strives to connect civil engineering programs with resources to meet program criteria for accreditation and to be responsive to the Civil of Engineering Body of Knowledge.

2. Background

2.1 Sustainability as a Student Outcome

In 2008, ASCE published *Civil Engineering Body of Knowledge for the 21st Century: Preparing the Civil Engineer for the Future, 2nd edition* (BOK2), which defines 24 foundational, technical, and professional outcomes early career civil engineers should demonstrate and expected levels of attainment that are aligned with Bloom's Taxonomy. Outcome 10: Sustainability, states:

The 21st century civil engineer must demonstrate an ability to analyze the sustainability of engineered systems – and of the natural resource base on which they depend – and design accordingly. [7]

Three levels of achievement are specified for attainment through the bachelor's degree:

- Level 1, Knowledge: Define key aspects of sustainability relative to engineering phenomena, society at large, and its dependence on natural resources; and relative to the ethical obligation of the professional engineer.
- Level 2, Comprehension: Explain key properties of sustainability and their scientific bases, as they pertain to engineered works and services.
- Level 3, Application: Apply principles of sustainability to the design of traditional and emergent engineering systems. [8]

An additional level of achievement (Level 4, Analysis) is specified for attainment through early career experience, namely the ability to "analyze systems of engineered works, whether traditional or emergent, for sustainable performance." [9] The FEE was formed to "promote, encourage, and support infusion of sustainability concepts into civil engineering undergraduate curricula consistent with ASCE BOK 2nd edition." [10]

ASCE and the Engineering Accreditation Commission (EAC) of ABET have modified civil engineering program criteria to require, beginning in Fall 2016, that curricula "… prepare graduates to… include principles of sustainability in design." [11] The EAC of ABET has also recently presented proposed criteria changes (Criterion 3: Student Outcomes) for all engineering programs that include the aim of providing "a framework of education that prepares graduates to enter the professional practice of engineering who are… knowledgeable in topics relevant to their discipline, such as… sustainability." [12] ABET EAC Criterion 3 currently requires programs to develop students' ability to "… design a system, component, or process to meet desired needs within realistic constraints…" [13] Sustainability is one of the constraints, but all of the other listed constraints - "economic, environmental, social, political, ethical, health and safety, manufacturability" - are intrinsically tied to sustainability.

2.2 Approaches to Incorporating Sustainability into Civil Engineering Curricula

Pearson Weatherton et al (2015) state, "Thinking and designing sustainably presents a multifaceted challenge; it involves human, natural, and economic resources, and thus requires multifaceted solutions derived from engineering, social, and economic perspectives." [14] This necessitates curricula that educate students across these multifaceted dimensions, and may involve a number of curricular and co-curricular approaches. Nickel

(2013) summarizes six broad strategies for incorporating principles of sustainability into curricula. Though the authors address curricula institution-wide, the strategies may be adapted to a single program such as civil engineering. The strategies include large-scale efforts such as creating new sustainability programs and smaller scale efforts such as those focused on students' ability to contextualize sustainability within a single course. [15] Other curricular approaches include creating new required or elective courses focused on sustainability [16-18]; implementing sustainability modules in existing courses [19-21]; and significantly revising existing courses to emphasize sustainability [22,23]. Co-curricular approaches include targeted internship opportunities and research groups that give students practical experience in applying principles of sustainability [24,25] as well as leadership, service learning, and study abroad programs [26-28]. Each approach presents unique challenges. For example, widespread implementation of modules requires faculty members' buy-in across the program, which may be difficult depending on their interest in and motivation for teaching sustainability. Faculty members may also find it challenging to deliver a module that was created by someone else, unless the module or lesson plan is extensively annotated. Despite the challenges, each approach also presents unique advantages. The use of course modules, for example, allows materials to be inserted into existing required courses rather than adding courses to an already crowded curriculum or solely offering an elective course that would limit exposure to students who choose to take it. Each program and faculty member must decide which approaches best fit their needs.

2.3 Subcommittee on Formal Engineering Education Activities

In May 2015, the chair of the FEE subcommittee met with civil engineering program chairs from across the country. The purpose of the presentation was to share with them information on the extensive resources that are already available to help them meet the new ABET program criterion for civil engineering programs. One primary message was that there was no need to "reinvent the wheel," so to speak; there is no shortage of materials currently available for incorporating sustainability into civil engineering curricula. A number of the chairs were already aware of this and shared some of the ways their programs are infusing sustainability into their curricula. Many, however, were not aware of the available resources. They wanted specific information on how to access resources and wanted ASCE to be the "go to" place to get that information. They were assured that the

ASCE COS, and specifically the FEE, would work with them and with ASCE staff to make this happen. The FEE began aggressively planning and implementing efforts to meet this need.

One response to the needs articulated by the program chairs was a webinar to share existing resources for incorporating sustainability into civil engineering curricula. The workshop had two primary foci: (1) examples of course modules developed and published online by the University of Texas at Arlington's (UT Arlington) Engineering Sustainable Engineers project and course modules and other learning resources offered by the Center for Sustainable Engineering (CSE) under the leadership of Syracuse University; and (2) an introduction to the ENVISION® rating system. The remaining sections of this paper discuss the webinar and the results of the participant survey along with recommendations to help shape future FEE initiatives.

3. ASCE eLearning Webinar

3.1 Webinar and Survey Design and Delivery

In November 2015, the FEE hosted a webinar entitled "Strategies for Including Principles of Sustainability in Civil Engineering Design" presented by four committee members. Dr. LivHaselbach, P.E. (Washington State University) described the three ASCE strategic initiatives and the Society's commitment to sustainability, the new ABET civil engineering program criterion that emphasizes sustainability, and general strategies for incorporating sustainability principles into civil engineering curricula. Dr. Yvette Pearson Weatherton, P.E. (UT Arlington) and Dr. Cliff I. Davidson (Syracuse University, CSE) provided an overview of example resources from their programs, and Dr. J.P. Mohsen (University of Louisville) discussed the ENVISION® rating system for use as a tool for course delivery of sustainable design topics and applications.

Following the webinar, participants were invited to complete a survey. The objective of the survey was to ascertain the respondents' perceived effectiveness of the webinar along with the specific content or structures that they felt would be most helpful for them to embed sustainability within their courses and curricula. The survey was designed by FEE members through several meetings and e-mail conversations.

3.2 Participant Overview

A total of 344 individuals registered for the webinar. Of these, 188 (54.7%) logged in to view the webinar; 71 (37.8%) completed the post-webinar survey. An additional 108 individuals viewed the archived webinar, but these individuals were not provided with the survey link. Of those that identified as faculty members and/or administrators, roughly one third (23/71, or 32.4%) reported their position/title as "faculty" and respondent ranks were fairly equally distributed among associate professors (11/71, or 15.5%), professors (13/71, or 18.3%), and non-tenure track faculty (10/71, or 14.1%). The largest fraction of participants identified as "other" (30/71 or 42.3%). They were likely postdoctoral scholars, graduate students, ASCE staff members, or perhaps, practitioners.

4. Results and Discussion

4.1 Respondents' Webinar Impressions

Participants were asked three multiple choice questions regarding their webinar impressions. Nearly every respondent (69/71, or 97.2%) indicated that the webinar was effective. The majority felt that the webinar complexity was "just right" (58/71, or 81.7%), although 12 respondents indicated that the webinar was "too simple/general" (16.9%). Most indicated that they would recommend the webinar to others (64/71, or 90.1%).

In addition to these multiple choice items, two open ended questions were asked to ascertain what webinar components respondents felt were *most* and *least* helpful. A total of 32 respondents (45.1%) provided a written description to the first question, "What aspects of the webinar did you find most helpful?" Four primary categories surfaced through analyzing these responses. First, 16 of the 32 respondents (50.0%) felt that finding out about available resources (e.g. UT Arlington and CSE modules) was particularly helpful. Second, eight of the respondents (25.0%) indicated that the webinar, in its entirety, was beneficial. Third, six of the 32 respondents (18.9%) explicitly mentioned the utility of the discussion on ENVISION®. Lastly, two respondents (6.3%) described the benefits of the webinar in determining strategies to address the ABET sustainability criterion within their courses.

A total of 26 (36.6%) respondents answered the question, "What aspects of the webinar did you find least helpful?" The primary criticism that surfaced from these responses (6/26, or 23.1%) was that there was too much information. One respondent wrote, "Each section of this webinar (modules, ENVISION®, etc.) could have been its [their] own separate webinar." Conversely, three respondents (11.5%) indicated that the webinar contained "too much review of the basics." The second primary limitation of the webinar, as expressed by six (23.1%) respondents, related to the

ENVISION® discussion. Again, this contrasts directly with the six respondents who thought the ENVISION® discussion was a primary strength of the webinar. Lastly, there was a potpourri of responses. For example, one individual pondered "how applicable the information is to students," whereas another indicated that the "discussion on course qualifying criteria" was not helpful. Two participants expressed technical difficulties.

4.2 Respondents' Interests in Sustainability

This section provides an overview of the respondents' general interest in sustainability, including the disciplinary topics that were of the most interest. Table 1 presents an overview of responses to four Likert scale items, where respondents selected one option along a five-point scale. As Table 1 indicates, 74.6% (50/67) of valid responses to the item, "Sustainability is important for the courses I am teaching now" were either agree or strongly agree. Likewise, 45 of the 63 (71%) valid responses to the item, "Sustainability is important for the research I do now" were either agree or strongly agree. Conversely, only 54.4% (37/68) of the respondents agreed or strongly agreed with the item, "Sustainability is an area in which I am interested, but I am not currently teaching or doing research in this area." Lastly, the majority of respondents (57/69, or 82.6%) disagreed or strongly disagreed with the item, "I do not have an interest in sustainability."

The second survey question asked participants to select among a list of sustainability topics to indicate those that were of interest to them. Respondents could select as many of the nine available options as they desired. Table 2 shows the number of participants that selected each item. The most frequently chosen topic (nearly 75% of respondents) was "sustainability rating systems". The next two most frequently chosen topics were "technical topics (e.g. how to design)" (73.2%) and "life cycle impact assessment" (70.4%). Only three topics were selected by less than half of the respondents; "land use" (49.3%), "community participation" (47.9%), and "access and mobility" (22.5%). Uncertainty about the meaning of "access and mobility" may have resulted in the low response rate for that item.

Table 1: Participants' Perceived Importance and Level of Interest in Sustainability

Sustainability is	Important for the course I am teaching now		Important for the research I do now		An area in which I am interested, but I am not currently teaching or doing research in this area		I do not have an interest in sustainability	
Response	Count	%	Count	%	Count	%	Count	%
Strongly Disagree	2	3%	3	4.8 %	12	17.6%	45	65.2%
Disagree	0	0%	1	1.6%	13	19.1%	12	17.4%
Neutral	15	22.4 %	14	22.2%	6	8.8%	6	8.7%
Agree	15	22.4 %	20	31.7%	18	26.5%	1	1.4%
Strongly Agree	35	52.2 %	25	39.7%	19	27.9%	5	7.2%
No/Invalid Response	4	-	8	-	3	-	2	-

Table 2: Sustainability Topics of Interest to Participants

Item	Count	Percentage
Sustainability rating systems (e.g. ENVISION®, LEED, etc.)	53	74.6%
Technical topics (e.g. how to design)	52	73.2%
Life cycle impact assessment	50	70.4%
Ethics and sustainability	46	64.8%
Socio-economic integration	42	59.2%
Sustainable project management	41	57.7%
Land use	35	49.3%
Community participation	34	47.9%
Access and mobility	16	22.5%

In addition to these nine items, respondents could select a tenth item called "other". These respondents were then prompted to describe their interests in writing. Nine responses were provided to this category. These included a wide span of topics, including social justice, energy use (in general), energy (of buildings) eco-cities, project-based learning in relation to campus sustainability, systems theory and integration, water utilization and treatment, and utilizing renewable energy within water infrastructures.

Next, respondents were asked to indicate what resources they felt would be important for them. Similar to the previous questions, participants could select as many options as they desired among a set of options. Table 3 provides an overview of the topics of interest in rank order. The most frequently selected option was "online course modules" (73.2%). The next three most salient categories were "project profiles/case studies" (69.0%), "downloadable articles" (67.6%), and "sustainability rating systems" (60.6%). Three topics were just above the 50% threshold: "standards" (54.9%), "textbooks that address sustainability" (52.1%), and "on-demand continuing education courses" (52.1%). Lastly, three items were selected by less than half of the respondents; "workshops" (49.3%), "conferences" (39.4%), and "sustainability blogs" (16.9%).

Table 3: Sustainability Resources of Interest to Participants

Item	Count	Percentage
Online course modules	52	73.2%
Project profiles/case studies	49	69.0%
Downloadable articles	48	67.6%
Sustainability rating systems (e.g. Envision, LEED, etc.)	43	60.6%
Standards	39	54.9%
On-demand continuing education courses	37	52.1%
Textbooks that address sustainability	37	52.1%
Workshops	35	49.3%
Conferences	28	39.4%
Sustainability blogs	12	16.9%

As before, respondents could also select an "other" option and then indicate what other resources they felt would be useful. Ten responses were provided here, and again varied widely. They included resources for training or

mentoring aids, assessment metrics, clear definitions, education tools, case studies (successful or unsuccessful and focused on real projects), engineering economics examples, and resources for practicing engineers.
Lastly, six participants provided written responses to the prompt, "Please share any comments on approaches for incorporating sustainability into civil engineering curricula." Rather than provide a content analysis of these responses, four of the verbatim responses are provided below.

- Ensure design for sustainability is included in introductory through capstone courses. Sustainability presently seems to be relegated to a scorecard or checklist. Whether in school or on the job, civil engineers need concrete guidance and approaches to achieving sustainable designs.
- I observed that students had weak quantitative skills, tried using sustainability context to motivate improving quantitative problem solving abilities in hydrology, water/wastewater chemistry…, economics & global warming potentials of different greenhouse gases. I was partially successful; it took covering the topic 3 times in lecture and on exams for students to improve. One successful exercise was estimating carbon footprint of smart devices (phone, tablet, laptop) that students carry using power consumption per unit area of screen.
- Philosophically, I believe that we need to ensure that the concept of sustainability is treated in a broad-spectrum manner (i.e., that it isn't compartmentalized into a course per se, but rather becomes part of the way that we do all of our work in a variety of ways). A student should come away with the sense that it is not so much a choice but rather a way of thinking, living, etc.
- Students graduating today need to have an understanding of the principles of sustainability so the future of our built environment can use less resources during construction and during operation, i.e. the life cycle costs of a given type of infrastructure project.

In sum, these responses appear to call for a holistic engineering education, where sustainability is not a peripheral focus but is embedded with other core engineering competencies.

5. Conclusion and Recommendations

The results of the participant survey from the ASCE Committee on Sustainability-sponsored webinar "Strategies for Including Principles of

Sustainability in Civil Engineering Design" show that there is strong interest in sustainability. Nearly three quarters of respondents indicated that sustainability is important to their current teaching and/or research. Slightly over half indicated interest, although they are not currently teaching nor doing research in the area. Analysis of the survey data yielded a few key recommendations the Subcommittee on Formal Engineering Education should consider as it seeks to meet program needs relative to sustainability curricular materials.

- Offer separate webinars to inform faculty and administrators about ABET requirements, resources such as learning modules, and rating systems rather than including them in a single presentation.
- When presenting information relative to sustainability in the curriculum, focus less on "the basics" and more on practical learning applications.
- Focus dissemination efforts on delivering information of the most interest to participants, namely online course modules, case studies, downloadable articles, and rating systems.

Because these recommendations are gleaned from a relatively small sample, it is suggested that the FEE deploy the interest and insights portion of the survey to civil engineering programs nationwide to obtain perspectives from a larger number and broader cross section of faculty members, administrators, and other stakeholders.

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References

[1] National Academy of Engineering Committee on the Engineer of 2020, Phase II, Committee on Engineering Education (2005).*Educating the engineer of 2020: Adapting engineering education to the new century*, National Academies Press, Washington, DC.

[2] United Nations (2015). *Transforming our world: The 2030 agenda for sustainable development*. {https://sustainabledevelopment.un.org/} (January 4, 2016).
[3] American Society of Civil Engineers (2015). "Committee on sustainability." {http://www.asce.org} (December 29, 2015).
[4] American Society of Civil Engineers (2008a). "Development of sustainability provisions in ASCE code of ethics." {http://www.asce.org/question-of-ethics-articles/nov-2008} (October 25, 2013).
[5] American Society of Civil Engineers Washington Office (2015). "ASCE 2015-2016 policies and priorities. {http://www.asce.org/public_policy_statements/} (December 29, 2015).
[6] ASCE Task Committee to Achieve the Vision of for Civil Engineering in 2025 (2009).*Achieving the vision for civil engineering in 2025: A roadmap for the profession*. American Society of Civil Engineers, Reston, VA.
[7] ASCE Body of Knowledge Committee of the Committee on Academic Prerequisites for Professional Practice (2008b).*Civil engineering body of knowledge for the 21st century: Preparing the civil engineer for the future,* 2nd Ed. American Society of Civil Engineers, Reston, VA.
[8] ASCE 2008a.
[9] ASCE 2008b.
[10] American Society of Civil Engineers (2015). "Formal engineering education committee." {http://www.asce.org} (December 29, 2015).
[11] ABET (2015a). "Criteria for accrediting engineering programs: Effective for reviews during the 2016-2017 accreditation cycle." ABET Engineering Accreditation Commission, Baltimore, MD.
[12] ABET (2015b). "Proposed revisions to EAC criteria 3 and 5 released for public comment." http://www.abet.org/accreditation/accreditationcriteria/accreditation-alerts/ (November 5, 2015).
[13] ABET (2014). "Criteria for accrediting engineering programs: Effective for reviews during the 2015-2016 accreditation cycle." ABET Engineering Accreditation Commission, Baltimore, MD.
[14] Pearson Weatherton, Y., Sattler, M.L., Mattingly, S.P., Chen, V., Rogers, K.J., and Dennis, B. (2015). "Multipronged approach for incorporating sustainability into an undergraduate civil engineering

curriculum."*J. Prof. Issues Eng. Educ. Pract.*141(2), C5014003-1 - C5014003-13.
[15] Nickel, R.M. (2013). Strategies for incorporating sustainability into the curriculum.Wisconsin Technical College System Foundation, Waunakee, WI.
[16] Allenby, B. (2007). "Sustainable engineering education: Translating myth to mechanism." *IEEE Proc. Symp. On Electronics and the Environment*, IEEE, New York, 52-56.
[17] Jahan, K., and Mehta, Y. (2007). "Sustainability across the curriculum."*Int. J. Eng. Educ.*, 23(2), 209-217.
[18] Bhandari, A., Ong, S.K., and Steward, B.L. (2011). "Student learning in a multidisciplinary sustainable engineering course."*J. Prof. Issues Eng. Educ. Pract.* 137(2), 86-93.
[19] Bielefeldt, A.R. (2011). "Incorporating a sustainability module into first-year courses for civil and environmental engineering students."*J. Prof. Issues Eng. Educ. Pract.* 137(2), 78-85.
[20] Sattler, M. L., Pearson Weatherton, Y., Mattingly, S.P., Chen, V., and Rogers, K.J. (2011). "Engineering Sustainable Civil Engineers."*Proc., Annual Conf. of the American Society for Engineering Education,* American Society for Engineering Education, Washington, DC.
[21] Christi, J.A., Heiderscheidt, J.L., Pickenpaugh, M.Y., Phelan, T.J., Pocock, J.B., Stanford, M.S., Seely, G.E., Suermann, P.C., and Twesme, T.M. (2015). "Incorporating sustainability and green engineering into a constrained civil engineering curriculum."*J. Prof. Issues Eng. Educ. Pract.*141(2), C4014004-1 - C4014004-8.
[22] Christi (2015).
[23] Lu (2015). "Integrating sustainability into the introduction of environmental engineering."*J. Prof. Issues Eng. Educ. Pract.*141(2), C5014004-1 - C5014004-6.
[24] Pearson Weatherton, Y., Chen, V., Mattingly, S.P., Rogers, K.J., and Sattler, M.L. (2012). "Sustainable engineering internships: Creation and assessment." *Proc., Annual Conf. of the American Society for Engineering Education*, American Society for Engineering Education, Washington, DC.
[25] Christi (2015).
[26] Athreya, K.S., and Kalkhoff, M.T. (2010). "The Engineering Leadership Program: A co-curricular learning environment by and for students." *J. STEM Educ.* 11(3), 70-74.

[27] Grudzinski-Hall, M. Jellison, K.L., and Weisman, R.N. (2007). "Engineering students in a global world: Lehigh University's Global Citizenship Program."*Online J. Global Eng. Educ.*, 2(1), 1-8.
[28] Conger, A.J., Gilchrist, B., Holloway, J.P., Huang-Saad, A., Sick, V., Zurbuchen, T.H. (2010). "Experiential learning programs for the future of engineering education." *Transforming Engineering Education: Creating Interdisciplinary Skills for Complex Global Environments*, IEEE, 1-14.

An Approach For Introducing Sustainability In Engineering Education

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Abstract

The world is suffering from overpopulation that is causing an increase of impervious surfaces in urban areas, depletion of natural resources, and degradation of the environment. Therefore, the principle of sustainable development, or sustainability, has been introduced into communities as a possible solution to these problems. Since engineers play an important role in the welfare of communities, they are increasingly being asked to address such problems in design and implementation of projects. On an academic level, this entails that engineering graduates possess the knowledge and understanding of sustainable concepts and methods for their adoption and implementation. However, the main challenge remains in integrating sustainability concepts into a curriculum that is already packed with courses and modules. The aim of this paper is to present an instructional methodology that can serves as a road map for academic institutions to integrate principles of sustainability into engineering education. The paper presents steps followed in establishing and implementing such methodology along with examples at the Department of Civil and Environmental Engineering at AUB.

Keyword: *Sustainability, Instructional methodology, Engineering Education, Civil Engineering*

1 Introduction

Since 1950, the world has witnessed an increase in its population by approximately three times [1], causing dramatic social changes, depletion of natural resources, and degradation of the environment. It is globally recognized that basic needs such as drinking water, clean air, energy and others cannot be sustained indefinitely [2]; therefore, it is the role of engineers to recognize these constraints and seek approaches to reconcile human needs with the world's capacity to sustain these needs. According to the National Society of Professional Engineers, it is the responsibility of the engineers to "dedicate their professional knowledge and skill to the advancement and betterment of human welfare" [3]. This responsibility being established, engineers have been seeking ideas and methods to drive down the adverse environmental, social and economic aspects of engineered products and infrastructure, to improve their environmental performance, and most importantly to shift the society towards adoption of what is often referred to as "sustainable development".

"Sustainable development" or "sustainability" are relatively new concepts that have emerged as a solution to the challenges that our world is facing. The debate around the meaning of sustainability has not been settled [4]; however, a classic and accurate definition describes it as "development which meets the needs of the present without compromising the ability of future generations to meet their own needs" [5]. In the past, societies had identified development as pure economic growth to attain high levels ofwealth [5]. However, after realizing the need to live within constraints and limitations, sustainable development has come through to ensure that economic development that meets the needs of the societies does not do so at the expense of depletion of natural resources, and socio-environmental degradation. By recognizing the importance of a sustainable lifestyle and embracing it, one main challenge remains in equipping the society with professionals who are able to address such challenges [6].

Many leaders in the engineering community have been opting to integrate sustainability thinking in engineering education because engineers are increasingly being asked to address such issues in their workplace [7]. However, integrating new concepts and materials into a curriculum that is already packed with courses, modules, and projects on covering a wide breadth of topics is a challenge by itself. One solution lies in implementing a transition from the current curriculum to another one that accommodates sustainable thinking and knowledge; however, reassessment of what is important and relevant for the students in a changing world, redesign of the curriculum and some of its courses, and its implementation, is a complex and lengthy process and such transition can take years. Therefore, until such process is carried out in its entirety, it is necessary to explore other venues for introducing sustainability in the engineering education in the immediate time frame.

The aim of this paper is to present an instructional methodology which covers sustainability in the discipline of infrastructure. This methodology can be considered as a road map for integrating sustainability thinking in the engineering education. It comprises of the individual involvement of the professor whereby it is his/her responsibility to initiate and adopt a teaching process that promotes sustainable thinking. It also aims at engaging the students into a continuing learning process that starts at the undergraduate level and continues all the way to graduate levels. The paper presents examples and case studies that have been implemented at the Department of Civil and Environmental Engineering (CEE) at the American University of Beirut.

2 Integrating Sustainability Concepts

This section discusses first three innovative and sustainable infrastructure practices that are being researched and implemented by CEE at AUB. Then, the steps followed in establishing a road map for integrating the associated principles in the curriculum are discussed.

2.1 Sustainability in Infrastructure

Geothermal pavements, use of construction and demolition waste (CDW), and pervious pavements are sustainable practices that have been researched extensively at AUB and implemented in pilot projects. Below is a brief description of these concepts:

1. Geothermal pavements, also known as energy harvesting pavements, are asphaltic pavement structures incorporating embedded pipe networks in their asphalt surface layer. In warm to hot climates, asphalt absorbs high amounts of energy due to its black color, and thus heats up significantly (reaching 70^{o}C in summer in Lebanon, and 85^{o}C in the Gulf). As water circulates in the pipes, its temperature rises due to the heat exchange thus lead to the cooling of the asphalt pavement. There are several benefits of such systems: reducing air temperature on top of pavement, urban heat island effect, reducing the energy needed to heat water, and increasing the life span of the pavement by reducing the risk of permanent deformation under the tires. In very cold conditions, the pavement could act as a snow/ice melting system by running warm temperatures in the pipe network.
2. CDW, construction and demolition waste, are materials that consist of the waste from debris generated during construction, renovation, or

demolition of buildings, roads, and infrastructure. CDW can be any type of materials such as concrete, wood, metals, etc. Reducing and recycling CDW is important as it conserves landfill space, reduces the environmental harm of illegal dumping, and reduces the depletion of natural resources.

3. Pervious pavements are characterized by a highly porous structure that allows rainwater to penetrate through them and percolate to the soil layers. Surface layer of such pavements can be of two types: asphalt or concrete. They have been widely used in Japan, Europe, and the United States of America because of their various advantages: controlling storm water runoff, reducing surface water pollution, reducing roadway noise, and, most importantly recharging underground aquifers or collecting rainwater.

These concepts will be used in section 0 as examples of sustainability projects applied by CEE at AUB as part of the teaching process.

2.2 Sustainability Concepts in Education

In this paper, the presented methodology for integration of sustainability thinking in the engineering education consists of four steps that presents the sequence of the steps of the path followed as part of a case study conducted at the CEE Department.

Step 1: Introduction of Sustainability in Materials and Pavements at the Junior Level

- **CIVE 370: Construction Materials and Technology**
- **CIVE 461: Highway Engineering**

Step 2: Supervised Community Service/Student Based Organizations

- **ASCE Summer Camp: Pervious Concrete Sidewalk in Village of Lala, West Bekaa**

Step 3: In-depth Understanding of Sustainability at the Senior Level

- **Application of Pervious Pavement in AREC**
  - **Experimental and Numerical Study of Geothermal Pavements**

Step 4: Special Topics At The Graduate Level

- **CIVE 798: Experimental Methods in Civil Eng'g Porous Media**
- **CIVE 798A: Sustainability in Pavement Design and Materials**

Figure 3: Sequence of steps followed in the instructional methodology implemented at AUB

The first step consists of informing the students about the general concept of sustainability. In this phase, students are considered to be in a passive phase that consists of acquiring and grasping information for use in later stages. The characteristics of this step are:

1. Happens during the first and second years of the undergraduate level.
2. Initiated by the professor since he/she possesses the required knowledge and it his/her duty to promote sustainable thinking in the class.
3. The professor can provide the students with published articles, which students have to read and present in interactive sessions.
4. An example consists of introducing the students to the definition, importance, and current practices of CDW in a Construction Materials and Technology course. Another example involves introducing in a

Highway Engineering course a glimpse of the practices and applications of geothermal and pervious pavements.

The second step aims at encouraging the students to participate in community service activities that are organized by students based societies such as the American Society of Civil Engineers. The purpose of such activities is to first promote the sense of responsibility in the student body, allow them to learn through collaborative work, and provide them with real life experience of a specific sustainable project. An example is a summer camp that is yearly organized by the ASCE Student Chapter at AUB, the aim of which is to employ the capabilities of the undergraduate students in serving rural and needy communities in different Lebanese regions. "Pervious Sidewalk in Lala" is one amongst the several achievements of the camp (Figure 2).

The teaching process continues in the third step where the students witness a transition from being an audience to a more engaged and active knowledge seekers. The characteristics of this step are as follows:

1. Spans over one academic year where students in their senior level are required to go in depth into the understanding, applications, and challenges of specific sustainable concepts such as geothermal pavements, pervious pavements and CDW.

2. This can be achieved in their Final Year Project (FYP), where each group of students have an advisor, and it remains the duty of the advisor to promote and propose sustainable research ideas. Moreover, it is his/her duty to supervise, guide, and evaluate the work being done.

3. At the end of the academic year, students are required to present the work done during the year along with the knowledge and experience acquired. The work will be evaluated by their professor judges.

4. To date, three groups of five students each have completed their FYPs on experimental and numerical studies of geothermal pavements and application of pervious pavements.

The last step is carried at the graduate level where special research topics are provided to graduate students based on their demand and orientation. These types of courses require the students to read, understand, and present for the class chapters of the specified book. Students are also required to conduct projects of their interests within the scope of the class.

3 - A Success Story: Pervious Concrete

Pervious Concrete Pavements has been the interest of students at different levels (undergraduate and graduate) as it presents a possible solution for the water shortage problem in the Lebanese regions. Students have focused on this concept from exploration to implementation, and its success presents a validation for the instructional methodology proposed in this paper.

3.1 Pervious Sidewalk: Lala village

The Student ASCE chapter at AUB organizes a yearly summer camp in rural and needy Lebanese regions. As part of community service activities, students have proposed to design a pervious concrete sidewalk that is 65 m in length for a school in Lala village in West Bekaa. The idea was feasible since pervious pavements are pavements that allow water to drain through it, and thus school students won't get wet while waiting for the bus during the winter season.

This project has created a collaborative environment as students from different engineering majors have participated in this project under the supervision and the guidance of the professors. Moreover, students were exposed to the different aspects of this project ranging from structural design of the sidewalk to its construction and operation. Figure 2 shows the site before and after the construction of the pervious sidewalk, while figure 3 presents the intermediate steps implemented in the construction of the sidewalk.

Figure 2: Before and After Completion of the Project

(a) (b)

(c) (d)

Figure 3: Sidewalk construction steps: (a) Placement of geo-membrane, (b) placement of aggregate layer and pipes, (c) placement of geogrid, and (d) pervious concrete placement.

3.2 Pervious Parking: AREC

The Agricultural Research and Education Centre (AREC) is a facility owned by AUB in the Northern Bekaa region. It consists of vast areas of agricultural land and various other facilities. It is situated in an arid climate and suffers from water shortage. At times, it either relies on wells, or buys water from external sources to irrigate its gardens and crops. As part of the Final Year Project, a group of five students took the task to design and build a pervious area in the major parking lot of the farm. During winter season, rain water will drain through the pervious area and the water will be directed through the pipes to a buried storage tank underneath the parking lot. The stored water can then be used for irrigation purposes. Figure 4 presents the steps undertaken in the construction of the pervious parking area.

(a)

(b)

(c)

(d)

Figure 4: Implementation steps of the pervious parking: (a) AREC Parking, (b) placement of aggregate layer and pipes, (c) pervious area, (d) water circulating to storage tank.

3.3 Pervious Concrete: Research and Innovation

Three graduate students who had participated in the previous mentioned activities (except for FYP) and have been part of this continuous learning process have showed extreme interest in pervious concrete pavements. These students have detected the lack and absence of universal methods and codes according to which the structural design and the performance of such pavements can be measured and evaluated. Therefore, by attending special topics classes such as CIVE 798: Experimental Design in Civil Eng'g Porous Media, students have researched and explored venues to develop a mix design methodology for pervious concrete. The work of the students is of high quality as it is being submitted to top notch conferences and journals in the civil engineering discipline. Figure 5 shows laboratory testing for the permeability of a pervious concrete sample done as part of the graduate students' work.

Figure 5: Laboratory testing for permeability of concrete

4 Conclusion

This paper focuses on an instructional methodology that has been implemented at AUB as part of a case study. Implementing pervious concrete into two different villages in the Bekaa region is a proof of the effectiveness of this methodology. This methodology can be adopted by universities as it is simple and does not require changing the curriculum.

However, the initiator is the professor and thus it is his/her duty to promote, stimulate and encourage sustainable thinking.

5 *REFERENCES*

[1] "Attitudes about Aging: A Global Perspective," Pew Research Center, January, 2014.

[2] "Engineering for Sustainable Development: Guiding Principles," The Royal Academy of Engineering, London, September 2005.

[3] *Code of Ethics for Engineers : Engineers' Creed,* National Society of Professional Engineers, 1954.

[4] M. Freyman, "An Exploration of Sustainability and its Application to Corporate Reporting," The Hauser Center for NonProfit Organizations at HARVARD University, 2012.

[5] J. Drexhage and D. Murphy, "Sustainable development: from Brundtland to Rio 2012," *United Nations Headquarters, New York ,* pp. 9-13, 2010.

[6] C. J. Desha, K. C. Hargroves, M. H. Smith and P. Stasinopoulos, "The Importance of Sustainability in Engineering Education: A Toolkit of Information and Teaching Material," in *Engineering Training & Learning Conference*, 2003.

[7] N. C. Hawkins, R. W. Patterson, J. Mogge and T. F. Yosie, "Building a Sustainability Road Map for Engineering Education," *ACS Sustainable Chemistry & Engineering*, pp. 340-343, 2013.

Declaration of
The 10th World Congress on Engineering Education
"Engineering Education for Sustainable Development"

We, engineering educators, gathered in October 2015 at the 10th World Congress on Engineering Education that was held in Beirut, Lebanon. We recognize the rapid changes in engineering education and the challenges of maintaining sustainability in the field. In responding to these challenges, we declare the following:

1. We acknowledge the need to develop and implement new curricula and teaching methods, when information and data are rowing exponentially. This will enable us to provide graduates with the necessary knowledge and skills they need to respond to problems they must deal with in a changing technological environment.
2. We are committed to developing both local and global solutions to engineering problems.
3. We affirm that problems and solutions transcend geographic boundaries. New disciplines are emerging and traditional definitions of disciplines should be rethought.
4. We recognize that engineers, more than ever, must be prepared for ethical professional practice in the new environment.
5. Engineering educators are prepared to work more closely with their governments and engineering companies, practitioners, and engineering societies to redefine the needs for engineering education, training and practice.
6. We are committed to working together with these stakeholders to redefine graduate attributes in order to meet the needs and the

demands of our rapidly changing society. This will influence the curriculum and teaching methods we develop.

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