Sustainability Challenges in Civil Engineering Education

A. I.Osofero[1], C.Udeaja[2], M. Corradi[3] and T.Vo[4]

Mechanical and Construction Engineering Department, Faculty of Engineering and Environment, Northumbria University, Newcastle upon Tyne, UK;
email:adelaja.osofero@northumbria.ac.uk[1],chika.udeaja@northumbria.ac.uk[2], marco.corradi@northumbria.ac.uk[3], thuc.vo@northumbria.ac.uk[4]

ABSTRACT

This paper focuses on how the design and delivery of the Civil Engineering (CE) program at two universities in Europe aims to develop graduates who are not only aware of the requirement for sustainability, but also satifies the aspirations of industrial, professional bodies and academic stakeholders. To achieve this, a review is undertaken to determine the main areas of interest in Sustainable Development (SD), particular attention being paid to the role of CE. Primary data is collected using two case studies, one on the CE program at a University in the North East (NE) of England and another in the central part of Italy The findings indicate that although efforts are already been made to integrate sustainability into the CE curriculum, there is a need for urgent interventions not only to ensure enhancement of students' knowledge on the theme, but also to convert this knowledge into responsible actions.

INTRODUCTION

The past three decades have witnessed an increasing global attention on Sustainable Development (SD), as a measure of addressing human activities and the climate changes in the environment (Huntzinger *et al*., 2007). Parallel to the global trend, the UK government has initiated several reforms to adopt new approaches to sustainable design and a construction practice that minimizes the use of natural resources and that are cost effective (Latham, 1994; Egan, 1998; Stern, 2007). Sinnott and Thomas (2012) recognized that this new approach is as a result of the need for practices that are sustainable. These will not only improve the environment (i.e. minimize the use of natural resources) but can also improve the economic viability of infrastructural projects that meets the expectations of the business, consumer, public and private sector clients. The Civil Engineering (CE) profession is central to the minimization of resource use and sustainable design/construction practices (Rackwitz *et al.,* 2005). Sinnott and Thomas (2012) argued that civil engineers are becoming aware of the need for achieving safe and environmentally sound infrastructure in a cost effective and ethical way. They further stated that the next generation of civil engineers need to acquire knowledge matching their broad roles in construction, from conceptual design to demolition of infrastructures. Huntzinger *et al* (2007, p. 218) added that the "modern engineer needs to be equipped with knowledge and skills to manage uncertainty and make judgments about the best course of action based on the available evidence". The 21st century sustainability challenges require that civil

engineers understand and systematically respond to the SD issues. Unfortunately, previous work by Fenner *et al* (2005), Kamp (2006), Huntzinger *et al* (2007), Sinnott and Thomas (2012) reveal that civil engineers' knowledge, skills and/or practices for SD are limited in a number of areas; as a result, civil engineers are not able to contribute to SD at an optimal level.

These deficiencies as experienced in the construction industry and educational systems have created the need for a major reform. There are few research works in this area that argue that there are synergies between the sustainability challenges and engineering education. These previous works are well documented in Fenner *et al* (2005), Kamp (2006), Huntzinger *et al* (2007), and Sinnott and Thomas (2012). However, there are other researchers who believe that the responses from academics are inconsistent and are done in an *ad hoc* manner, which only meets the needs of the universities. This research argues that that the 21st Century is now seen as the time for Higher Education Institutions (HEI) especially in the UK to embrace new working approaches. This is critical if the HEI wants to remain competitive and at the same time meet the ever increasing expectations of its stakeholders. This research will address the issue of incorporating sustainability education within the CE curriculum, which addresses professional competencies in all areas of the CE programmes. It will seek to identify a benchmark that effectively delivers the sustainability knowledge within the CE programmes. The research will seek to propose a framework that will support the development of desired sustainability competencies. The study will report on current approaches of sustainability education through the examination of a Northern University in England and a Central Italian University case studies; thereby identifying broad and specific changes needed to bring about deeper incorporation of sustainability in CE education. The work outlined in this paper attempts to identify and map the sustainability activities within the CE programs. To achieve this, the research starts by offering a clear understanding of SD and the importance of embedding sustainability in the curriculum. Interviews with the CE staff and documentary evidence of the programme documentations will be used to collect evidence of the current state of affairs in the two universities. The findings will be utilised in mapping the extent to which sustainability activities are embedded in the CE curriculum.

LITERATURE REVIEW

Since the publication of Brundtland (1987), sustainability and SD have become an important concepts and common currency in many industries both in the UK and globally. The idea of sustainability is more prevalent in today's society than at any other point and time. As demand for products, infrastructure and lifestyle amenities grow, it is important to seek a balance between meeting the needs and the impact of the process of meeting the needs on the environment. This section will assess previous work on SD Education in HEI, with a particular focus on CE Education.

Importance of embedding sustainability in CE education. Civil Engineers role in SD, which is now absolutely central to the practice of CE, needs to be reflected in their education and training (ICE, 2013). The Engineering Council (2013), the body with regulatory responsibility for the engineering profession, requires engineers to undertake their activity in a way that contributes to SD. The main

way to enable students to develop new values, skills and knowledge in SD is through developments in curricula and pedagogy. Reflecting the central role that SD will take in practice, there is a requirement for SD to be embedded in undergraduate teaching: 'prevalent throughout the engineering education programme' in the undergraduate courses that are accredited by the Joint Board of Moderators (JBM, 2013).

Previous research. This research project cuts across various disciplines such as in the in the construction and engineering fields and employs variety of strategic and concepts. Consequently, this section outlines a number of issues and approach that have been applied in these fields to embed SD in the curriculum. A review conducted on past research on similar theme can be summarized as follows: Siller (2001) described a method for presenting concepts of SD to first-year CE students using pedagogical techniques related to critical thinking development; Chau (2007) presented efforts made to reorient CE education to promote the concept of sustainability in an undergraduate curriculum in Hong Kong; Al-Tamimi *et al* (2011) evaluated a CE curriculum in the context of sustainable materials; Beheiry *et al* (2012) examined typical engineering curricula and identified specific courses in the areas of CE where sustainability can be injected with minimum disruption to the structure of the course and/or its connection to other courses with the intended degree; and Glendinning *et al* (2013) developed a new programme at Newcastle University which was an example of sustainability embedded into the CE curriculum and of University-industry collaboration. This review, though not exhaustive, represent the wide range of past research work worthy of consideration towards determining the appropriate strategy in incorporating SD in CE programme.

Challenges of embedding sustainability in CE education. Universities in the UK are obliged to embed sustainability as a key theme in undergraduate CE programs, but initial consultations with the teaching staff on these programs suggest that this is an area of the undergraduate teaching curriculum that many universities find difficult to define, deliver or assess (JBM, 2013) . There was a need for further teaching guidance for educators. Broadbent (2012) also provided practical suggestions to help educators embed sustainability in the undergraduate engineering curriculum. This was based on the findings of desk research, conversations with educational institutions that were recognised as demonstrating best practice in this field, and on the findings of a half-day conference for representatives from the HE sector on embedding sustainability in the undergraduate curriculum. In addition, because of close interrelation between education and industry demand for students, industry interest is also a key element of SD education (Engineering Council, 2013). This interrelation will ultimately ensure that the programme is continuously updated with current industrial practice and that our research will feed its way back into the programme (Glendinning *et al* 2013).

METHODOLOGY

To build on the existing studies, this research will use a case study approach to examine how universities in the NE of England and the central Italy incorporates sustainability education in its curriculum. The case studies used are

major universities in Europe responsible for training engineering students for their professional careers; its programmes have to be comprehensive and up to date. This is absolutely critical to maintaining their relevance in the future and to keep attracting applicants from within the region and beyond, particularly on the CE degree programme. The first case study is a UK example of CE undergraduate 3 years BEng full-time programme with an option of a 4th year MEng. In the first year, the students' learning focuses on the fundamental principles of CE, including a UK-based site visits. The second year concentrates on the CE practice and also prepares the students for the optional placement year. It is imperative to note that students will be strongly encouraged to undertake a placement year as it will provide opportunities to apply the knowledge gained in the first 2 years of their study while also preparing them for the final year. In the final year of BEng, the curriculum will focus on the broader role of civil engineers whilst the students further develop relevant work related and academic skills. The second case study is an Italian example of 3 years BEng programme and an additional 2 years to achieve the MEng qualification. The first two years covers the fundamental issues of engineering, preparing the students of the theoretical concepts and principles of general CE. The third year of the BEng focuses on the praticality of the CE aspects in real world. The third year is also seen as a formative year for the students to visit other European countries. It is important to emphasis at this point that the focus of this research is for only the BEng undergradate degree and as the MEng will not be considered.

The main form of data collection was semi-structured interviews with the university staff members to identify the requirements for sustainability education. This then led to a categorization of different contextual issues relating to the mapping of sustainability in the context of the CE curriculum. The semi-structured interviews were adopted due to the level of investigation it allows without losing control of issues to be discussed. It was also anticipated that this method of data collection will enable a deeper understanding of the issues involved and offer the potential to obtain sensitive data that may not have been possible through questionnaire. Documentary sources were also used to support the evidence obtained from the interviews. In the context of this case study, the documentary sources information were gathered from the CE programme documentations (i.e. modules, specifications, etc.) and also from the documentary analysis of the professional bodies within the CE fields (i.e. ICE, IStructE, CIHT, CIWEM) to establish how sustainability knowledge competencies are achieved. The documentary sources also provided background information about the case study as well as information about sustainability education phenomena being investigated.

The interviews used face-to-face techniques to facilitate close interaction between the researchers and the respondents. This ensured the researchers' control of the process and also provided the opportunities to clarify doubts arising from either the interview questions or the responses. The questions designed mainly border around how sustainability education is incorporated within the modules, curriculum and the entire CE programme. A purposive sampling method was adopted for the selection of the interviewees. This method is also known as judgemental sampling and allows the researchers to select interviewees according to predetermined criteria which will ensure the research questions are answered; thus meeting the objectives of the research. In this study, the interviewees identified at management level using purposive sampling, recommended useful

potential candidates in the teaching team for further interviews. In total, up to five interviews within the CE groups of the two universities were carried out. New issues and headings generated from the interviews and documentary evidence were added to the structure and the findings are presented in section 4.0 below.

FINDINGS

The research findings including document analysis and the interviews responses can be captured by developing a sustainability framework CE degree programme. The developed framework incorporates the current and the perceived future roles of the civil engineers in the global sustainability agenda. In addition, the research findings suggests that it is imperative for CE graduates to be knowledgeable and aware of key sustainability issues as identified in the proposed framework to varying competence levels. The key sustainability issues as identified by the present research are presented in Table 1. The knowledge areas in sustainability relevant to CE education are grouped into 9 high level categories, with each of these containing several subcategories. Other issues not readily identifiable from the review were identified through the conducted content analysis. These also led to the refinement of the sustainability framework relevant to the CE degree programme. Critical discussion of the extent of integration of sustainability in the studied CE curriculum and authors' recommendation are presented in the next section. It should be noted that the findings from this work builds on previous research by Ekundayo *et al* (2011) and Broadbent (2012).

Table 1. Recommended sustainability education framework for CE curriculum.

Category A	a) Sustainable development overview and principles b) Climate change and global warming issues c) Impact of the construction industry on the environment d) Sustainable construction concept e) Role of CE in sustainable development	**Category C**	a) Protecting and enhancing the built and nat. environment b) Environmental Impact Assessments (EIA) c) Environ. Assessment Methods: BREEAM, LEED, Green Star d) Reducing energy consumption e) Reducing greenhouse emissions f) Carbon Agenda g) Waste reduction principles h) Brownfield development i) Natural resources, renewable and non-renewable materials j) Water usage and Sustainable Transportation Plan
Category B	a) Changes to Building regulation b) Code for Sustainable Homes c) Energy Performance Certificate (EPC) d) The Kyoto protocol e) Relevant EU Directives f) Sustainable Construction Strategy g) Sustainable Procurement Action Plan		
Category D	a) Corporate Social Responsibility (CSR) b) Ethical issues such as ethical sourcing of materials and labour c) Equity and social justice d) Community development and social inclusion e) Health & safety f) Employment, training and education g) Social assessment methods (e.g. Design Quality Indicators, KPIs and benchmark, etc.) h) Cost Benefit Analysis (i.e. impact of human factors)	**Category E**	a) Cost planning and management b) Value management or engineering (cost of alternative materials and designs) c) Sustainable procurement strategies d) Feasibility studies e) Whole-life appraisal/ Life cycle costing f) Financial incentives (such as subsidies, climate change level, aggregate tax, carbon credit, Brownfield land tax, etc)

Category F	a) Renewable energy technologies (Photovoltaic, Wind Turbine, Biomass, etc) b) Green Build. Materials c) Rain water harvesting and Grey water collection systems d) Professional and management software packages e) Modern methods of construction: offsite production, precast mat., lean constr., etc. f) Passive design methods such as day lighting, intelligent facades, carbon storage, etc g) Supply chain management h) Effective information control and management	**Category G**	a) Avoidance of ozone depleting products in buildings b) Consideration of materials with Global Warming Potential c) Low level ozone / smog - causes and effects d) Transport emissions e) Indoor Air quality, VOCs, TVOCs f) Acid rain g) NOx emissions h) Contaminated land, investigation and remediation principles i) Contaminated water and water courses j) Noise/sound pollution k) Air pollution measurement and control
Category H	a) Climate change effects - flood risk, mitigation and adaptation b) Water conservation and management in buildings c) Building Regulations water consumption calculator d) Technology for water efficient sanitary appliances e) Behavioural issues and water consumption Controls Reuse / recycling water in buildings f) Storm water management/Water attenuation/ Rainwater storage systems g) Green roofs h) Principles, technologies and material choices for sustainable urban drainage systems (SUDS) i) Foul drainage / sanitation - internal and external, grey water systems	**Category I**	a) Land use and development planning principles and practices b) Sustainable Develop. Guidelines c) Sustain. communities d) Eco Town principles e) Transport planning / Car use / parking / pedestrians, cycling f) Ecological / biodiversity assessments of sites g) Brownfield site policies h) Derelict and contaminated land issues i) Proximity of housing to employment areas, mixed use develop. j) Landscaping and social / environmental sustainability k) Designing for flexibility / adaptability l) Construction and wildlife conservation, wildlife partnerships m) Building conservation principles and practices n) Urban regeneration strategies o) Reuse of buildings / Land p) Site investigation techniques

DISCUSSIONS AND CONCLUSIONS

A growing awareness, in HEI and other key education stakeholders, on the importance of incorporation of sustainability in engineering education is evident. This is particularly true for CE, a profession that has been charged with the responsibility of ensuring sustainable infrastructures development. This work has examined how sustainability is embedded into the education of students on CE degree curriculum in HEI in UK and Italy. Staff members, responsible for the delivery of modules on these programmes were interviewed in addition to the examination of available documentary evidence, such as module descriptors.

The general findings from this work seem to corroborate conclusions of previous studies on similar theme. The study indicates some gaps in the CE curriculum and public expectations on graduate civil engineers. In addition, possible reasons for this gap have been identified: 1. Engineering profession as a whole has distance itself from the responsibility of creating sustainable environment and for a long time focused primarily on solving engineering problems. However, as the realisation of the environmental threats are becoming

obvious to all, the general public and particularly engineering professionals are becoming more responsible to the environment by championing SD. The situation will not change overnight, the realisation and increase in awareness will be an on-going issue that will require concerted effort by everyone involved in CE education to ensure the integration of sustainability. 2. Lack of know-how on SD is also noticed among the interviewed academia. Possible reasons for this is the lack of training on this issue or total resistance to change, giving that most CE programmes have been running for decades. 3. Inadequate time, for preparation and lecture delivery, has also been noted as a major obstacle in incorporating sustainability in the CE curriculum.

In addition, the research findings suggest that doubts exist amongst the respondents on the best way to integrate sustainability in the existing CE curriculum at the examined higher institutions. Further research could focus on strategies, presented in form of a template, which will illustrate how the sustainability agenda can be integrated in the curriculum design and the actual delivery. Furthermore, it is suggested that existing interdisciplinary platforms should be utilised, and new ones created where necessary, to engage students in hands-on interdisciplinary sustainability challenges. It is suggested that CE programs should adoptmeasures of assessing the extent of integration of sustainability agenda into their curriculum without necessarily developing an extra teaching module to achieve this.

In conclusion, there seems to be some underlying willingness to learn and a generally positive attitudes towards the sustainability theme among the academics at the examined HEI. However, general lack of guidance and training on the best implementation technique forms a gap between the general positive attitude and pratical implementation. Continuing Professional Development (CPD) traning programmes for CE teaching staff, on sustainability as it relates to CE activities, is reccomended amongst other strategies in bridging this gap.

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