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Surveying the state of higher education in energy efficiency, in Australian engineering curriculum

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ABSTRACT

This paper presents the method and results of a survey of 27 of the 33 Australian universities teaching engineering education in late 2007, undertaken by The Natural Edge Project (hosted by Griffith University and the Australian National University) and supported by the National Framework for Energy Efficiency. This survey aimed to ascertain the extent of energy efficiency (EE) education, and to identify preferred methods to assist in increasing the extent to which EE education is embedded in engineering curriculum. In this paper the context for the survey is supported by a summary of the key results from a variety of surveys undertaken over the last decade internationally. The paper concludes that EE education across universities and engineering disciplines in Australia is currently highly variable and *ad hoc*. Based on the results of the survey; this paper highlights a number of preferred options to support educators to embed sustainability within engineering programs, and future opportunities for monitoring EE, within the context of engineering education for sustainable development (EESD).

1. Introduction

Engineers are increasingly being called upon to innovate in a range of new areas, including improving the energy efficiency (EE) of engineered systems, processes and products, along with developing and maintaining renewable and low greenhouse gas emissions energy generation technologies. The Intergovernmental Panel on Climate Change (IPCC) has been warning since 1988 that all nations need to stabilise their concentrations of carbon dioxide (CO_2) equivalent emissions, and that this will require significant global reductions in the order of 60–80% by 2050 [1]. However, the International Energy Agency (IEA) also forecasts that if policies remain similar to those currently in place, world energy demand is set to increase by over 50% between now and 2030 [2]. Although renewable and low-emission options are already available, energy demand must be reduced to facilitate a timely and cost effective transition. Clearly then, there is a need for commitment around the globe to both reduce greenhouse gas emissions from energy supplied and reduce energy demand [3,4]. Such a commitment would involve the development of tailored sophisticated responses involving every country and across all engineering and design disciplines, addressing significant variations in national policies, natural endowments, levels of development and per capita emissions. Given the complexity of such solutions, a common theme for all countries would be a concerted education and curriculum renewal effort, particularly as activities in this area have considerable lag times before graduates begin making key decisions in their field.

More than a decade ago, the United Nations Environment Program (UNEP), World Federation of Engineering Organisations (WFEO), World Business Council for Sustainable Development (WBCSD), and the École des Ponts Paris Tech (ENPC) [5] supported a key international conference on engineering education and training for sustainable development. One of the key outcomes of this conference was a collective realisation that engineering education has a critical role to play in equipping graduates with the knowledge and skills necessary to create the capacity within the engineering profession, to deliver solutions and underpin the global economy's future.

The United Nations has defined education for sustainable development (ESD) as encouraging '*changes in behaviour that will create a more sustainable future in terms of environmental integrity, economic*

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viability, and a just society for present and future generations' [6]. According to the World Federation of Engineering Organisations (WFEO), for engineering this means playing, '*an important role in planning and building projects that preserve natural resources, are cost-efficient and support human and natural environments*' [7]. Hence, effectively undertaken engineering education for sustainable development (EESD) is a broad area covering technical, social and economic aspects.

Although there is increasing research on ways to improve engineering education for the 21st Century, there has not yet been a detailed assessment of the global state of EESD [8]. In the absence of such information, this paper begins by discussing a number of surveys that have been used to assess the progress of higher education institutions (HEIs) in EESD. In particular, it summarises the results of key surveys over the last two decades on the extent to which EESD is embedded in curriculum. The paper then presents the findings of a recent major survey in Australia undertaken by the authors, which contributes to the body of survey literature to-date in the sub-topic example of energy efficiency (EE) education, which includes energy demand (i.e. reducing energy consumption), and energy supply (i.e. changing to low-carbon options). The authors note that EE is not considered to be a potential proxy or replacement indicator for sustainability content, rather it is an example of a new area of practice that needs to be rapidly integrated into engineering courses, in addition to topics like water and materials efficiency. Indeed, such topics can be included as ESD subtopics or instruments, but ESD is more than their individual contributions. Further to the Australian survey findings on the sub-topic of EE, the authors outline a number of options for improving EE content and monitoring, synthesising experiences of researchers attempting other curriculum renewal initiatives and from the authors' own experiences.

1.1. Global context: a lack of information

A 2003 report by the US National Council for Science and the Environment noted that baseline information about the status of sustainability education and practice in any nation is largely absent [9]. A detailed review of EESD literature by Desha et al. [8] found that this situation has remained largely unchanged. Despite growing calls for EESD, the paper concluded that there has not yet been a comprehensive assessment of the extent of sustainability content included in engineering education globally, or an assessment of whether critical sustainability literacies have been incorporated into engineering curriculum. Assessments of sustainability within universities still tend to be at the campus operations level [10], focusing on the generation of policy statements and the implementation of environmental management systems, rather than at the curriculum level for a particular discipline.

This lack of information is problematic in raising awareness about the need for curriculum renewal – where an early question is likely to be '*what is the extent of the problem and how do we know this?*' – and in subsequently gaining funding and resources for curriculum renewal initiatives. The authors suggest three possible reasons for this lack of information gathering to-date, including:

1. Difficulty in assessing the extent to which sustainability knowledge and skills are embedded within the curriculum.
2. The time and resource intensive nature of conducting a global survey across the thousands of departments offering engineering degrees in many different languages.
3. Potential reluctance of professional organisations, accrediting bodies or the universities themselves to undertake the survey, due to possible planning, resourcing and accreditation implications of what might be found.

With these considerations, it is perhaps not surprising that there has not been a strong call from any one group for a comprehensive review, despite it being an important step in establishing what needs to be done to enable a global transition to EESD.

2. An overview of key surveys on the state of EESD

Despite the lack of a comprehensive review of the state of EESD, a small number of surveys have been undertaken over the past decade that may be used as an indication of progress towards EESD, briefly highlighted in the following paragraphs.

In 1997, the World Engineering Partnership for Sustainable development (comprising WFEO, the International Federation of Consulting Engineers (FIDIC), and the International Union of Technical Associations (UATI)) circulated a questionnaire to national members of WFEO in an endeavour to provide an improved benchmark for engineering progress, concluding that, '*the survey does not indicate a strong or consistent approach to the environment and sustainable development in engineering education or that, on a country average, much more than 10 per cent of time in 10 per cent of courses is devoted to these aspects*' [5].

Between 2000 and 2002, the University of Surrey (UK) and the University of Melbourne (Australia) collaborated to undertake a survey of a sample of international engineering students on their level of knowledge and understanding of sustainable development, which as far as its authors were aware, was the first of its type [11]. The researchers suggested from the findings of 21 respondents from 40 invitees that the level of sustainable development knowledge was not satisfactory, and that significant knowledge gaps existed within the curriculum [11].

In 2002, engineering educators at the Royal Melbourne Institute of Technology invited 21 Australian universities to participate in a survey in relation to the status of sustainability education in these institutions. Assessing responses received from approximately a quarter of these HEIs, the researchers concluded that, '*a handful of universities are engaged in this education for a wide range of their students, and in some universities more students of particular disciplines are gaining the exposure. However, there are clear barriers to the introduction and expansion of sustainability education*' [12].

Following the 2004 Declaration of Barcelona, in 2006 Chalmers University of Technology, Delft Technical University, and the Technical University of Catalonia, produced a report called *The Observatory*, which assessed the status of EESD in European Higher Education, in collaboration with the Alliance for Global Sustainability [13]. The report benchmarked a sample of 51 European Universities who participated in providing survey data, against examples and statements from outside Europe. The 2006 report concluded that, '*to date, there is no European University that shows sufficient progress in EESD to be considered an inspiration*' [13].

In 2007, as part of the Forum for the Future's *Engineers of the 21st Century Programme*, two young engineers surveyed 499 young engineers (online) who had graduated 2–10 years ago with regard to sustainability literacy [14]. The surveyors suggested, based on the findings, that almost two-thirds of past graduates had felt that sustainability was either important or very important to their job role today; however, 40% of their university lecturers had inadequate knowledge of sustainability and only 30% had a positive to passionate attitude about the subject.

Between 2007 and 2008, the US Centre for Sustainable Engineering conducted a benchmarking survey on the extent of sustainable engineering education within 1368 engineering departments (or the equivalent), with just over one-fifth of the invited 364 American universities and colleges participating [15]. The researchers concluded that, '*the engineering education community is now at a critical juncture. To date, there has been a significant*