



Review

A systematic review of the literature on integrating sustainability into engineering curricula



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ABSTRACT

Higher education plays an important role in furthering the sustainability agenda, as reflected in a growing body of literature. While there have been several recent reviews of this work, these have been limited in scope and do not explicitly discuss implementations of sustainability in higher education curricula. In response, this paper presents a comprehensive, systematic review of the literature on integrating sustainability into curricula at both an undergraduate and postgraduate level of study in one particular subject area – engineering. A total of 247 articles, of which 70 were case reports, have been analyzed. Twelve future research questions emerged from the analysis, including: the exploration of the knowledge and value frameworks of students and teachers; the exploration of stakeholder influence, including by accreditation institutions, industry partners, parents, and society; and, the use of competencies to evaluate implementations. It is hoped that answering these questions will help to enhance education such that engineers are prepared, engaged, and empowered to confront the environmental, social, and economic challenges of the 21st century.

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1. Introduction

For several decades, there has been a strong political will and commitment towards sustainability and sustainable development. An important means of furthering the sustainable development agenda is via education, including higher education. Following the launch of the 1983 World Commission on the Environment and Development (WCED) report, various scattered initiatives were implemented to integrate sustainable development concepts and approaches into higher education. Chapter 36 of Agenda 21, the outcome of the 1992 United Nations Conference on the Environment and Development in Rio de Janeiro, later highlighted the important role that education can play in realizing sustainable development; but a further push to stimulate its introduction was needed. Thus, the United Nations Decade for Education for Sustainable Development was initiated from 2005 to 2014, which provided an impetus for integrating sustainability into education, including higher education. This important catalyst awakened and motivated some (but far from all) educators in many curricula to integrate sustainability into their courses, curricula, research, outreach, and on-campus greening activities. A detailed history of the initiatives taken in society, education, and higher education to foster sustainable development is now available in [Lozano et al. \(2013, 2015a\)](#).

A survey by [Murphy et al. \(2009\)](#) found that more than 80% of US universities have some level of course activity related to sustainability and sustainable development, but the extent of this activity varies. In general, initiatives can be divided into two different strands: (i) initiatives that aim to put sustainability into the curriculum; and, (ii) initiatives aimed at making universities themselves more sustainable, e.g. in the form of sustainable procurement, sustainable campuses, etc. The focus of this study is on the curriculum. It presents a systematic review of the literature on the integration of sustainability and sustainable development into engineering curricula. The focus is upon engineering curricula in particular because of the crucial role it plays in the development of countries ([Lucena and Schneider, 2008](#)), such as through the provision of critical infrastructure services and the creation of essential goods and products.

Engineering educators were not the leaders in making curricula changes to incorporate sustainability into their educational work ([Mulder et al., 2012](#)). They began to integrate environmental engineering into education around 1994 based upon dialogue and papers that were presented at several conferences focused on environmental efficiency issues for engineers. The scope of these conferences was later broadened out to sustainable development with the first Engineering Education in Sustainable Development Conference held in 2002 ([Mulder et al., 2010](#)). Since then, there has been an increasing effort to integrate sustainability and sustainable development issues into engineering curricula, and this is reflected in an increasing body of literature on the topic. But it is unclear where we are on our journey towards introducing and applying sustainability concepts, approaches, tools and paradigms within engineering education. This paper takes stock of the field.

While there have been several recent literature reviews on sustainability and sustainable development in higher education, these have not typically been in the context of engineering education. These reviews are also restricted to a relatively small sample of papers ([Figueiró and Raufflet, 2015](#); [Blanco-Portela et al., 2017](#)) or to a focus on descriptive measures (e.g. [Karatzoglou, 2013](#)). For example, [Figueiró and Raufflet \(2015\)](#) reviewed 63 papers from 12 journals (from 2003 to 2013) to identify challenges, teaching techniques, and curriculum orientation in management education while [Blanco-Portela et al. \(2017\)](#) reviewed 35 papers (from 2000 to 2016) to identify the drivers and barriers to change. It is argued here

that a broader, less myopic view is required to adequately take stock of what has been achieved to date. Moreover, there is no review that isolates articles on case implementations to explore what has actually been done in practice. In response, this study started by asking: What is the current state-of-the-art on integrating sustainability and sustainable development into engineering curricula? A comprehensive, systematic review of the literature was conducted to answer this question in terms of: (i) research; and, (ii) practice. Based on this review, the study outlines important future research questions. It is hoped that answering these broad research questions will contribute to providing engineering education with the means to help engineers confront the environmental, social, and economic challenges of the 21st century.

The remainder of this paper is organized as follows. The method followed to conduct the systematic literature review is outlined next in Section 2. Section 3 then presents the results before an overall discussion is provided in Section 4. Final conclusions are then summarized in Section 5.

2. Method – systematic review of the literature

This paper starts by asking:

What is the current state-of-the-art on integrating sustainability and sustainable development into engineering curricula?

The focus is on how sustainability has been integrated into higher education (at the undergraduate and postgraduate level) rather than on what aspects of sustainability have been incorporated. This largely relies on case reports of the process of integration or implementation rather than on cataloguing what material, modules, or programs have been developed. Consequently, this study uses a systematic review of the literature rather than secondary data from university websites to answer this question. We also do not assess the contribution of existing curricula to sustainability and sustainable development; for this, the reader is referred to [Lozano \(2010\)](#) and [Lozano and Young \(2013\)](#).

A systematic procedure for retrieving and selecting the articles (following [Tranfield et al. \(2003\)](#)) was used. Subsections 2.1 to 2.3 outline the approach adopted for sourcing, screening, and analyzing the articles, respectively.

2.1. Sourcing the articles

The bibliographic database used for sourcing the articles was Scopus – due to its large coverage, e.g. compared to Web of Science, and its accuracy in terms of citation counts, e.g. compared to Google Scholar. It is recognized that there is an extensive literature in the form of books and white papers, but it was not possible to have access to all relevant books for a systematic review. In order to keep the number of articles reasonable and to ensure the quality of the sources, the search was further restricted to peer-reviewed articles. Scopus was queried in April 2017 using the terms: ‘Sustainable AND Engineering AND Education’; ‘Green AND Engineering AND Education’; ‘Sustainable AND Engineering AND Curriculum’; and ‘Green AND Engineering AND Curriculum’. While the keyword ‘Green’ may introduce a bias towards one dimension of sustainability (i.e. environmental), it is included since it is often applied in engineering. To keep results to a manageable number, the search was restricted to the title, abstract, and keywords of papers. No limit on the subject area was applied to reflect the multidisciplinary nature of engineering education. Document type was limited to ‘articles’ and ‘reviews’. There was no restriction on the year of publication or the journals considered (beyond being peer-reviewed). For the four search terms, 1,046, 203, 307, and 66 articles were retrieved, which makes a total of 1622 articles.

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