Journal of Cleaner Production xxx (2014) 1–8

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Educational initiatives

A method to quantify the integration of renewable energy and sustainability in energy degree programmes: a Finnish case study

Helena Mälkki [a, *], Kari Alanne [b], Laura Hirsto [c]

[a] Dept. of Civil and Environmental Engineering, Aalto University, P.O. Box 15300, 00076 Aalto, Espoo, Finland
[b] Dept. of Energy Technology, Aalto University, P.O. Box 14100, 00076 Aalto, Espoo, Finland
[c] Faculty of Theology, University of Helsinki, P.O. Box 4, 00014 Helsinki, Finland

ARTICLE INFO

Article history:
Received 22 November 2013
Received in revised form
1 October 2014
Accepted 2 October 2014
Available online xxx

Keywords:
Energy engineering curriculum
Learning outcomes
Relevance ratio
Renewable energy
Sustainability
Aalto University

ABSTRACT

The key factors affecting the sustainability of our society are research, conversion, delivery and the efficient use of energy resources. The expertise, attitudes and sustainability awareness of decision-makers determine far-reaching political decisions made regarding whole energy systems as well as the choices available for individual consumers. Despite the significance of education with respect to renewable energy and sustainability, the position of these topics remains unclear in degree programmes. Measuring the relevance of these subjects can be considered a central issue in terms of promoting a more sustainability-oriented perspective on education strategy formation. Therefore, this paper presents a new curriculum development method for stimulating discussions about the learning outcomes of the degree programmes. This method has been used to calculate a proposed relevance ratio (RR) index, which indicated the relative weight of renewable energy and sustainability topics for energy studies in Aalto University's energy degree programme. The benefits of this RR index include the ability to reveal the strengths and weaknesses of selected contents in the curricula. However, more research is needed to integrate wider working life skills with the students' learning path as a means of promoting student expertise. This new tool will be universally applicable and quantify the desired contents of learning outcomes in degree programmes at universities.

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1. Introduction

World energy consumption is increasing in non-OECD countries by 90 percent between 2010 and 2040 due to the use of fossil fuels (IEO, 2013). Biofuel and food production compete with each other on the use of land area and threaten biodiversity at the global level (EC, 2006; EC, 2010; Uslu et al., 2010). In Europe, the use of energy from renewable sources is promoted by European Union (EU) energy policies (Beurskens and Hekkenberg, 2011; EU, 2009; Ruska and Kiviluoma, 2011). From these perspectives on energy issues, sustainability is a crucial component in educating engineers in energy conservation, improved technology, and increased use of energy sources with low emissions, and in building a foundation for sustainable consumption patterns for the world's growing population.

Many recent studies have identified the need for sustainability in curriculum and in higher education institutions (Adomβent et al., 2014; Hancock and Nuttman, 2014; Lozano and Lozano, 2014; Wals, 2014). The role of education for sustainability has been increased and perceived as a catalyst for innovation in education since the establishment of the United Nations Decade for Education for Sustainable Development (DESD) 2005–2014 (Nolan, 2012). Nolan (2012) has concluded that the challenge of sustainable development needs to be accompanied by changes in attitudes, values and lifestyles, and the strengthening of people's capacities to bring about change. Although these new challenges are recognised in sustainability education, there remain ongoing challenges in integrating sustainability and renewable energy into energy education (Acikgoz, 2011; Kandpal and Garg, 1999; Karabulut et al., 2011). Engineers need training to use renewable energy technologies (IRENA, 2011) and to be aware of the principles of sustainability (Littledyke et al., 2013; Lozano, 2010; Müller-Christ et al., 2014).

A diverse nature of sustainability does not only mean increasing the share of renewable energy or improving energy efficiency; economic, ecological and social dimensions also need to be addressed in education (Byrne et al., 2013; Svanström et al., 2008).

* Corresponding author. Tel.: +358 40 8248748.
E-mail addresses: helena.malkki@aalto.fi, hemalkki@gmail.com (H. Mälkki), kari.alanne@aalto.fi (K. Alanne), laura.hirsto@helsinki.fi (L. Hirsto).

http://dx.doi.org/10.1016/j.jclepro.2014.10.012
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Here, tools, good ways and systems' models are essential for assessing desired competencies for sustainability in curricula (Lozano and Lozano, 2014; Rorarius, 2007; Zamagni et al., 2009). Yarime and Tanaka (2012) have mapped sixteen sustainability assessment tools for higher education institutions. They stated that more work is needed to analyse the content of courses, to develop methodologies and to encourage efforts towards sustainability. The role of sustainability in its broader sense is still not clear in degree programmes and teaching about renewable energy and sustainability takes place at an 'encyclopaedic level' (Bojic, 2004; Karabulut et al., 2011). It seems that there is still a need for systematic methods to measure the extent to which degree programmes deal with renewable energy and sustainability.

The aim of a degree programme is to enable continuous learning and ensure that the prerequisites of the courses strengthen overall learning outcomes (Levander and Mikkola, 2009). Gradually, each course supplements and builds students' comprehensive competencies. This type of cumulative learning procedure is referred to as constructivist learning theory, which is based on understanding, knowledge, experience and reflection (Tynjälä, 1999). In comparison, Segalàs et al. (2013) have divided these competencies into three dimensions: 1) knowledge and understanding, 2) skills and abilities, and 3) attitudes. These competence dimensions have also been referred to as formal, informal and non-formal skills (Malcolm et al., 2003; MacVaugh and Norton, 2011). The aim of this paper is not to address the whole competence phenomenon. Instead, we focus on knowledge, and understanding and the formal contents of learning outcomes. We later use the term contents to refer to these viewpoints.

Students need appropriate teaching methods that embed theory, practice and self-reflection as well as the social environment to better develop their expertise (Barnett and Coate, 2005; Tynjälä, 2008). Eskandari et al. (2007) have identified a crucial need to revise curricula due to changes in the types of engineering roles and responsibilities within the field. Integrating both expertise and education is a multi-step, iterative and continuous process involving several stakeholders (Davidson et al., 2010; EHEA, 2012; Klen and Hoffman, 1992). Planning the content of curricula requires the commitment of the university community to collaborate with working life (Mälkki and Paatero, 2013; Barth and Rieckmann, 2012; Hirsto and Löytönen, 2011). For example, the results of regular surveys of students who have recently graduated offer a good basis for planning and developing working life competencies in engineering curricula (TEK, 2012b; Korhonen-Yrjänheikki, 2011; Oivallus, 2011).

According to a FinnSight 2015 report (2006), expertise in renewable energy and sustainability involves many elements, e.g. knowledge of ecosystems, criteria for the biomass, environmental management of the product systems, efficient use of energy and new technologies. This expertise is built on a solid basis of fundamental physics, field knowledge and practical skills. Expertise will be imparted in practical learning environments and through learning by doing, working on multi- and interdisciplinary teams and using problem-solving approaches (Crawley et al., 2007; Peltonen et al., 2013; Tynjälä et al., 2006). Fig. 1 shows the composition of a sample engineer's expertise, which is modified from a study by Mälkki et al. (2012).

Universities have a particular challenge when it comes to embedding sustainability-related knowledge and skills within courses and curricula (Desha and Hardgroves, 2010), and teachers need support and interdisciplinary co-operation in this endeavour (Allenby et al., 2007; Byrne et al., 2013; Davidson et al., 2010; Ferrer-Balas et al., 2008). Collaboration between teachers, academic staff and various stakeholders plays an important role in enabling the desirable changes within degree programmes (Barth and Rieckmann, 2012; Hirsto and Löytönen, 2011; Mälkki and Paatero, 2012). These changes within courses can be supported by using appropriate teaching and learning methods (e.g. Jennings, 2009; TEK, 2012a; Tynjälä et al., 2003). In particular, participatory student tasks are considered essential for internalising the concept of sustainability (Segalàs et al., 2008), as well as for facilitating students' development as experts (Litzinger et al., 2011). In terms of core curriculum planning, curriculum analysis has proven to be a useful tool for identifying and defining important and less important content for degree programmes and courses (Blom and Davenport, 2012; Carr et al., 2012; Miller and Crainn, 2011).

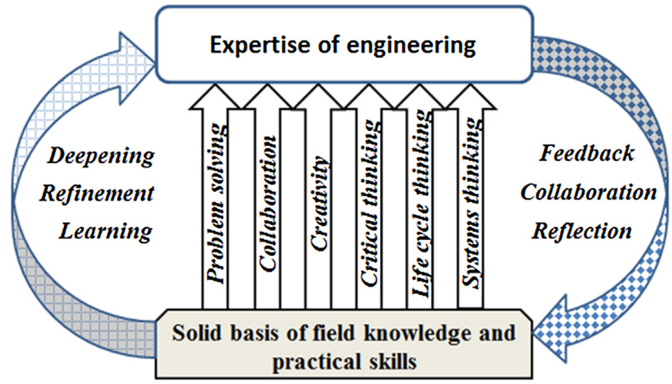

Fig. 1. Composition of an engineer's expertise, based on Mälkki et al. (2012).

European universities have implemented the Bologna model since 2005 in Bachelor's and Master's degree programmes, which has resulted in a need to intensify the development of degree programmes and their accreditations (Lindblom-Ylänne and Hämäläinen, 2004). Universities have also updated their course information in terms of curriculum development by defining the learning outcomes at the course and programme levels. The Finnish Educational system has been successful in the educational rankings of the OECD Programme for International Student Assessment (PISA). Finland is also well known for its innovations, such as mobile technology and computer games, which have maintained the country's economic competitiveness for several years. Sustainable forest management is essential for Finland's national economy due to its dependence on forests, forest bio-products and ecosystem services. Wood is used in the production of renewable energy and in construction. In addition to traditional forest industry products, there are also new wood-based bio-products, such as biodiesel fuel, composites, biopolymers, pharmaceuticals, cosmetics and well-being products (Forest Finland, 2011). Hence, education in renewable energy and sustainability is necessary in all sectors of society and as an essential part of product design.

Aalto University is one of the leading Finnish universities. Its goal is to become a world-class university by 2020. It has set an ambitious goal to integrate sustainability and responsibility into all teaching and research by 2015 (Aalto University, 2013). However, the position of these topics remains unclear in degree programmes. Measuring the relevance of these subjects can be considered a central issue in terms of promoting a more sustainability-oriented perspective on education strategy formation. To that end, an attempt has been made to promote curriculum development by developing a computer-aided tool called STOPS (Software for Target-Oriented Personal Syllabus for Students) in the School of Engineering at Aalto University (Auvinen, 2011; STOPS, 2011). The STOPS tool is described in Section 2, "The case study, material and methods".

In this paper, we propose a new method that includes a relevance ratio (RR) index, which generates added value for the use of

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