Education for cleaner production in Information and Communication Technologies curriculum

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Abstract: Environmental protection and green energy became top priorities for many countries. One of the fields contributing to the transition towards a sustainable society is information and communication technologies (ICT). As a result, the significant attention was attracted among enterprises by green ICT in the face of rapidly changing technological trends. According to European e-Competence Framework, sustainable development has become one of the key competencies required and deployed by ICT professionals. Despite the demand for qualified specialists with high expertise in green ICT and ICT for greening, sustainability has quite recently gained acceptance in ICT curricula. The goal of this article is to show the emergence of green ICT and ICT for greening especially in education. The article also analysis different framework for implementation of sustainable development into ICT curricula, and presents current trends and perspectives in development of educational programs in the mentioned field.

The article is aimed at academic and research professionals in the fields of sustainable development and green technologies, with the goal of improving educational initiatives to address the societal demand for sustainable development.

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Keywords: Sustainability; green ICT; ICT for greening; higher education

1. INTRODUCTION

Currently our world is facing complex challenges, which require urgent attention. These challenges include climate change, water, air, and soil pollution, resource depletion, and many other ecological problems. Therefore, environmental protection and green energy became top priorities, and, consequently, different worldwide organisations and governments of many countries have integrated various principles of sustainable development into national policies and programs (Australian Government, 2010; METI, 2008; fSuryawanshi et al., 2013). IEEE (www.ieee.org) and IFIP (http://ifipwg511.org) have specific working groups on Green IT, and IFAC has Technical Committee on Greening by ICT (TC 8.3) but not in green ICT.

The information and communication technologies (ICT) proved to be an important sector in ensuring sustainable development. For example, the SMART 2020 (GeSI, 2008) and SMARTer 2020 (GeSI, 2012) reports recommended the intensive deployment of ICT both for enhancing the monitoring of the environment and human activities and for distributing smart ICT systems to mitigate pollution, food quality and supply problems, etc. They could also be used to solve waste, resource management problems (Digiesiet et al., 2015, Yetik et. al., 2009) and energy constraints (Ili_c and Lui, 2011). Thus, the concept of sustainable computing is playing an important role in the transition towards a sustainable society (Hilty and Lohmann, 2013).

As a result, due to fast changing technological trends, today enterprises pay a significant attention to green ICT (Fortas, 2013; Kable, 2014; UKCES, 2014). For example, new communication protocols were implemented in networks (EnergyWise, IEEE 802.3az), new metrics were defined and are currently used in Datacenters such as PUE (Power Usage Effectiveness), new compilers are developed to analyse software efficiency (Greenspector), new concepts such as circular economy, service economy are progressively implemented in ICT companies, and finally e-waste is a well-known issue to be considered. These examples clearly show that new competences have to be introduced in ICT curricula to be in line with company activities.

According to European e-Competence Framework (n.d.), sustainable development has become one of the key competencies required and deployed by ICT professionals. This competence “estimates the impact of ICT solutions in terms of eco responsibilities including energy consumption; advises business and ICT stakeholders on sustainable alternatives that are consistent with the business strategy; applies an ICT purchasing and sales policy which fulfills eco-responsibilities”. Employees have to be able to “monitor and measure the ICT energy consumption; apply recommendations in projects to support latest sustainable development strategies; master regulatory constraints and international standards related to ICT sustainability”.

Lack of qualified specialists with high expertise in networking, computing, and programming, who are able to design, develop, deploy, and maintain both pervasive computing systems and communication architectures for sustainable development, has led to necessity of incorporation sustainable development principles into higher education. However, sustainability has quite recently gained acceptance in ICT curricula (Klimova et al., 2016). For
example, Plessuis (Appelman et al., 2013) showed that in the Netherlands, sustainability held a systematic place in only 10% of IT curricula. Mann (2008) while conducting the research in the field of computing education for sustainability was looking for the whole programs in this area. However, “there aren’t any”.

The purpose of the paper is to answer the question, whereas any changes in the educational landscape in the field of green computing in recent years.

The paper is organised as follows. In the next section, theoretical basis of implementing sustainable development into ICT curricula is described. The section entitled “research method” provides the methodology of selection, extraction and analysis of the master degree programs in the field of sustainable computing. Next section describes tendencies for development of SD programs. Research results provide an analysis of the databases, and summary of the program description.

2. THEORETICAL BASIS OF IMPLEMENTING SUSTAINABLE DEVELOPMENT INTO UNIVERSITY CURRICULA

The question of universities’ contribution to sustainable development capture attention of many authors. Anand et al. (2015) described a strategy for the integration of sustainable development into higher education in Canada. Holm et al. (2015) presented relevant sustainability aspects of higher education curricula in the Nordic countries. They also show how different fields of study reflect different categories in this regard.

Universities’ contribution to sustainable development has different aspects. Thus, Lozano et al. (2015) presented results from a worldwide review of commitment and implementation of sustainable development in higher education. Their paper provided a list of categories for university assessment including institutional framework, campus operations, research, outreach and collaboration, etc. Implementation of SD into education was also considered as an essential factor. Survey results proved importance of the integration of SD courses in educational programs, invitation of SD guest lecturers, and creation of SD-oriented master programs.

There are many opportunities to check the level of involvement of SD into education (Boman, 2013, Lozano, 2010). Boman (2013) suggested three criteria based on the amount of content that refers to environment and sustainable development. Criteria selected to assess curricula contributions to SD, such as “coverage of environmental issues and material into existing course, specific SD course; concept in regular course” were also presented by Lozano (2010). He has also described STAUNCH - sustainability tool for assessing university’s curricula, in particular, its contribution to software development.

Researches proved that incorporation of SD into university’s curricula is a complex task. For several decades, scientists have been creating different generic matrix, frameworks and methodologies in order to facilitate incorporation of sustainability into education (Anand et al., 2015; Cai, 2010; Ceulemans and Prins, 2010; Holm et al., 2015; Mann, 2008). Those frameworks and methodologies could be used for separate courses, program, university level, etc. (Rusinko, 2010). Penzelstadler and Fleischmann (2011) discussed a possible process of integration of sustainability concepts into a degree course, indicating the necessity of motivating students and raising awareness. According to these authors, the process should comprise three stages, namely a seminar targeting interested people, a lecture series, and integration into the software engineering syllabus.

Table 1 presents a brief summary of three frameworks described by Cai (2010), Ceulemans and Prins (2010), and Mann (2008). The result of the analysis shows that, despite different terminology, the main methodologies for incorporation of SD into university curricula is quite similar.

The first and, probably, the simplest way of incorporation SD into university curricula is the development of separate courses. It is called centralized (Cai, 2010; Mann, 2008) or vertical approach (Ceulemans and Prins, 2010). More complex and appropriate approach towards software development is incorporation of SD within different courses of the curriculum or complete re-design of curricula with the focus on sustainability.

Table 1. Analyses different frameworks

| Main idea: (Cai, 2010) | Mann (2008) | Ceulemans and Prins (2010) |
|-------------------------|-------------|--------------------------|
| Separate SD course | New green computing course: “developing a new course” | Centralized approach: “sustainability related subject matters in one or two courses” | Vertical approach: “organization of separate SD courses within the curriculum” |
| Several independent modules and courses | Modular approach: “development independent green computing learning modules and projects to incorporate into existing courses” | Distributed approach: “many different computing courses address sustainability issues” | Horizontal approach: “SD is interwoven within different courses of the curriculum” |
| Re-design of curricula with the focus on sustainability | Integrative and transformative approach: “re-design of some computing courses with sustainability as one of the top priorities” | Blended approach: “programs focusing on sustainability” | |

Although applications of ICT in environmental education are relatively broad, the concept of sustainability has gained an acceptance in ICT curricula just recently. In the Netherlands, for example, sustainability held a systematic place in only 10% of IT curricula (Appelman, 2012). The framework proposed by Cai (2010) was one of the first frameworks for integration of sustainability into ICT university curriculum. Table 1 adapted main idea from his work: development of new course “Green Computing”, design of independent green computing learning module to implement them into the courses (modular approach); redesign of some computing courses with sustainability as
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