Computing Education for Sustainability

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Abstract

Computing plays a critical role in sustainability. This paper examines the status of education for sustainability in computing. There are clearly stated high level declarations for sustainability education, and much activity and success in other disciplines, notably engineering and business. Despite this, computing lags behind. The paper concludes with a proposal for an agenda for computing education (both teaching and research) that incorporates sustainability at all levels.

Keywords: *computing education, education for sustainability, computing research, agenda*

1   Introduction

An awareness of sustainability issues is increasingly an expectation of graduates in every discipline – including computing. In this paper we attempt a review of the state of Computing Education for Sustainability (CEfS). In a previous paper (Mann and Smith 2007) we examined the links between computing and sustainability and argued that we need to articulate a sustainable future for computing professionals. This paper outlines an action plan for embedding sustainability within the computing curriculum.

Computing plays a critical role in sustainable development. Cortese (1999, 2001) stressed the importance of articulating the future. As computing professionals we need to examine what role we see computing professionals playing in that future. As computing educators charged with creating those computing professionals we are doubly responsible, as we also have to put in place the system to get us there.

The paper begins by introducing the high level declarations for sustainable education. We then explore options for embedding sustainability into programmes and look at how other disciplines have addressed this issue. We then examine seven aspects of computing education for evidence of CEfS and conclude with an agenda for CEfS.

2   Sustainability context

United Nations Secretary-General Ban Ki-Moon (2007) argues that "information and communications technologies (ICT) are crucial in spurring development, dignity and peace". He argues that we should "turn the digital divide into digital opportunity" and that ICT should be promoted "in fighting poverty, illiteracy and disease, in protecting the environment and empowering women and girls".

In 1992, Stevenson and Moll argued that computing is at the centre of our society and that computing therefore should be a platform for social development and indeed had a special responsibility for doing so: "linking culture through computers…can provide a nucleus for building cohesiveness"

Unfortunately, computing does not have a good track record at leading social change. Stevenson and Moll (1992) point to a survey of all the departments in the U.S. and Canada that grant a Ph.D. in computing (broadly defined) that showed that no Afro-Americans, only twelve Hispanics (1.5%), and 107 women (13%) received Ph.D.'s in 1991.

3   Imperatives for Education for Sustainability

From the highest levels, the need to address education for sustainability (EfS) (in addition to education *about* sustainability) is being articulated.

In this section we give an overview of the history of education and sustainability: starting with history at an international level and then focussing on frameworks for considering EfS.

3.1   International declarations

In 2004, the United Nations declared 2005-2014 the Decade of Education for Sustainable Development, recognising the pressing need for "education for sustainable development" as "a life-wide and lifelong endeavour which challenges individuals, institutions and societies to view tomorrow as a day that belongs to all of us, or it will not belong to anyone." The role of computing gets a special mention: "the process of globalization coincides with a fundamental transformation to knowledge-based societies – largely driven by information and communications technologies (ICTs) – where knowledge and information increasingly determine new patterns of growth and wealth creation and open up possibilities for more effective poverty reduction and sustainable development".

The United Nations (2004) argues that universities and higher education institutes can contribute to sustainable development in several ways:

- "First, by giving sustainable development a place in all university curricula and educational and research programs."

- "Second, by playing an important role as local knowledge centres for sustainable development."

- "Third, by making sustainable development a leading principle in their own logistics and managerial processes." United Nations (2004)

The call for sustainability in education is not new. Nicolaides (2006) reviews a long history of international efforts to promote links between sustainability and education. In 1977 UNESCO's Tiblisi conference set out objectives for environmentally conscious educational institutions. The 1987 Bruntland Commission was followed by UNESCO calls for strategies on environmental education. The International Association of Universities signed the Talloires Declaration in 1990: "all university graduates are environmentally literate", "curricula for an environment that is sustainable".

In 1992 the Rio Earth Summit 92 Agenda 21 includes Chapter 36 (page 264) which identified four major thrusts of Education for Sustainable Development:

- Basic education must focus on imparting knowledge, skills, values, and perspectives that encourage and support citizens to lead sustainable lives

- Reorienting Existing Education at all Levels to Address Sustainable Development: Rethinking and revising education from nursery school through university to include more principles, skills, perspectives, and values related to sustainability in each of the three realms - social, environmental, and economic - is important to our current and future societies

- Developing Public Understanding and Awareness of Sustainability

- Training: All sectors of the workforce can contribute to local, regional, and national, sustainability. The development of specialized training programmes to ensure that all sectors of the workforce have the knowledge and skills necessary to perform their work in a sustainable manner has been identified as a critical component of ESD.

In 1993 the European universities adopted the University Charter for Sustainable Development (known as the Copernicus charter) and Agenda 21 was reaffirmed at the Johannesburg Earth summit (the Ubuntu declaration). More recently, all programmes have come together under the UN Decade of Sustainable Education 2005-2014, and operationalised in the Global Higher Education for Sustainability Partnership (GHESP).

Significantly, the distinction is made that literacy in sustainability involves all professional groups. Cortese (1999) states:

"Unless higher education responds quickly to ensure that all of their graduates, regardless of their fields of study, are environmentally literate, then it is unlikely that our future leaders will demonstrate the analytical thinking, the will or the compassion to adequately address complex issues such as population, climate change and social equity." and

"Environmental specialists alone will not help us move toward a sustainable path. A compartmentalized approach further reinforces the assumption that environmental protection should be left to environmental professionals. All humans consume resources, occupy ecosystems and produce waste. We need all professionals to carry out their lives and activities in a manner that is environmentally sound and sustainable."(Cortese, 1999)

3.2   New Zealand imperatives

Locally, the Tertiary Education Strategy 2007 – 2012 introduces sustainability as a key direction from the first line: "Tertiary education and research underpin the realisation of New Zealanders' goals and aspirations and the sustainable development of New Zealand's economy and society" (Ministry of Education, 2007).

Under the goal of "economic transformation", tertiary education providers are asked to address social and economic outcomes: "Balance progress with environmental sustainability by providing New Zealanders with the knowledge and skills to understand and work within environmental constraints" (Ministry of Education, 2007).

At a curriculum level, the 2006 draft Curriculum Document (Ministry of Education, 2006) also includes reference to sustainability at a high level, as a component of the key competency of Participating and Contributing: "(Students) understand the importance of balancing rights, roles, and responsibilities and of contributing to the quality and sustainability of social, physical, and economic environments."

Sustainability is also suggested as a theme which provides "opportunities for engaging students and integrating learning across the key competencies and the different learning areas." (authors' emphasis) (MOE, 2006)

3.3 Implications

We have then a strong call for a cross disciplinary, sustainable approach to higher education. Unfortunately (or perhaps fortunately), as Nicolaides (2006) adds, "it is far from a being a simple matter to include an ecological dimension".

University Leaders for a Sustainable Future (ULSF, 2001) provide an assessment framework to promote consideration of sustainability. Their Sustainability Assessment Questionnaire (SAQ) is organized according to seven critical dimensions of higher education:

1. Curriculum
2. Research and Scholarship
3. Operations
4. Faculty and Staff Development and Rewards
5. Outreach and Service
6. Student Opportunities
7. Institutional Mission, Structure and Planning

Second Nature, an international advisory organisation, has a similar framework, which focuses on enabling higher education to incorporate sustainability. (Second Nature, 2005).

Notions of the hidden curriculum notwithstanding, the focus of this paper is on academic aspects of sustainability, although operational aspects are clearly important (Creighton 1997). Meigs (2005), for example, conducted a survey of 33 peer institutions in the USA in preparation to implementing sustainability initiative. He found that energy conservation was the most widespread strategy. It was a universal theme for all respondents with many millions of dollars being saved nationwide. Other trends, in order of frequency, were recycling, green purchasing, green building, transportation and water conservation.

4 Curriculum and research

In this section we consider how sustainability can be included in education, firstly from a generic perspective and then examining how EfS has been applied in sister disciplines. This section is

independent of computing, CEfS is considered in section 5.

4.1 Sustainability programmes

There are many options for the development of new programmes (or re-branded existing programmes) in sustainability. ULSF (2005), for example lists degree programmes that meet the following criteria:

- focus on the social, economic, and environmental dimensions of sustainable development

- oriented toward systems or integrated thinking

- interdisciplinary

There are both Undergraduate and Post-graduate programmes in sustainability. Fogg (2006) points out that this is a significant change in academia- "Ten years ago, students interested in studying sustainability had few options. They usually had to craft their own programs of study in environmental-science departments".

4.2 Sustainability as course(s) in programmes

Institutions committed to sustainability often feature key topics in their course offerings within traditional degree programmes (ULSF 2001), e.g. Globalization and Sustainable Development; Environmental Philosophy; Nature Writing; Land Ethics and Sustainable Agriculture; Urban Ecology and Social Justice; Population, Women and Development; Sustainable Production and Consumption; and many others.

Unfortunately these courses are perhaps not helpful examples for computing. In crowded curricula (McGettrick *et al.* 2005), it is unlikely many computing programmes could make room for such topics.

In design education, Cao *et al.* (2006) take a different approach. They described a course based on a "cradle to cradle (C2C) design model" (McDonough *et al.* 2003). This course, they argue fills "an apparel and interior education and curriculum void related to the environmental impact of design and merchandising decisions". The C2C approach assumes "that products can be designed to have another cycle or nutrient function after their useful lives". Cao *et al.* used a problem based learning approach to "bring the science and industrial application together".

Cao's course is explicitly science-based but within a design context: "the topics of this course will include the environmental impact of raw material, manufacturing, dyeing, finishing, product lifecycle, and other issues related to apparel and interior design's influence on the environment". The C2C model is explicitly used in the curriculum document and the learning outcomes are clearly stated; "after taking this

course, interior and apparel design and merchandising students have a better understanding of the relationships among their design and buying decisions and environmental issues".

4.3   Sustainability throughout a programme

There are strong arguments for the integration of sustainability across the curricula.

In describing a vision for the transformation of higher education, Second Nature (2005) argue that education needs to address three key areas: content, context and process. The content of learning suggests a focus on

"embracing interdisciplinary systems thinking to address environmentally sustainable action on local, regional and global scales over short-, medium- and inter-generational time periods. Education would have the same "lateral rigor" across the disciplines as the "vertical rigor" within the disciplines. Compartmentalized knowledge without connection to larger system interactions results in viewing many interdependent challenges—such as population, consumption, economics, health and the environment—as separate and often competing. The net results are often narrow, ineffective solutions, or worse, more harmful to people and the environment in another place or another time. Systems thinking is essential to developing a shared framework for understanding and addressing complex nonlinear systems that are characteristic of society and the natural world.

Cortese (2001) argues that the **context** of learning needs to change to make the human/environment interdependence and values and ethics a central part of teaching in all the disciplines, rather than isolated as a special course or module in programs for specialists. Meanwhile the **process** of education needs to emphasize active, experiential and collaborative learning and real-world problem solving on the campus and in the larger community.

The pressure for adopting a sustainable approach for higher education can also come from student demand. Berringer (2006), for example, describes how, with full support of the institution, students developed and undertook a sustainability audit in Canada. This audit included operations, learning and research and community (support for student green groups etc). Berringer describes how the development of the framework for the campus audit was explicitly used as a participatory teaching tool. Interestingly, both the processes of developing the framework and carrying out the audit were used as the basis for experiential project-based teaching. In a further twist, indicators that they were unable to complete have become action research projects for staff and students to develop measurement techniques.

It is important to realise that when looking for EfS at an integration level, we need to be looking at the milieu: higher level documents, mix of research outputs, interdisciplinary projects and so on.

4.4   Discipline examples

4.4.1   Chemistry as example

In 2001 The Copernicus Campus undertook a study to identify existing concepts of sustainability in chemistry education on a European university level. They found "hardly any" complete programmes with special reference to sustainability. Instead "the topic is rather integrated into conventional chemistry education so that aspects of sustainability always remain closely connected to practical problems in chemistry". They go on to say that this is not due to regulations or curriculum requirements but rather is "in the hands of individual professors to integrate this element into the course of studies".

They do describe some "exemplary programmes". In one: *"sustainability and responsible care have found their way into lectures and seminars as complex principles. In these universities lectures and seminars introducing sustainable development are offered within the chemical faculties, in which apart from environmental protection global and local aspects of sustainability are of utmost importance. Problems in chemistry are seen in their reference to technology and industry, but also with regard to their interaction with society and ecology. In the respective lectures and seminars students get to know the connections between technology and society in order to gain insights into possibly conflicting aims. In this respect, great emphasis is placed on conveying important norms and values. Political basic conditions for an industrial ecology are taken into consideration. In the courses on sustainable technology students should learn to formulate social, economic, ecological and technical criteria for sustainability, which enable them to evaluate and compare various technologies. In a course on sustainable enterprising with technology students have to write a business plan for an enterprise selling a sustainable product, service or process."*

The survey (Copernicus Campus 2001) also found several cases of sustainability being used as a mechanism for cooperation between universities and industry with research centres into solar cells, ecological cities, urban water management and sustainable buildings.

4.4.2   Engineering as example

Cortese (1998) challenged engineers to envision a sustainable future and then challenged them to articulate their role, in designing the new future, in achieving it, and in maintaining it. He argued "engineers must lead this new industrial revolution":

*"I believe that there is a special role for civil/environmental engineers in the future. Rather than being the engineers that primarily design technologies to control or remediate pollution, I believe the **environmental engineers will be the interdisciplinary, systems specialists** who will bring together, coordinate and manage all the specialists to solve complex environmental problems and*

promote sustainable development…Moreover, all engineers must play a much stronger role in the public policy process to provide the right incentives for industry and others to move on a sustainable path so that engineers can be encouraged and supported to design sustainable technology".

Fenner *et al*. (2005) describe a range of developments aimed at introducing sustainability concepts into engineering education at Cambridge University. Fenner *et al.* (2005) state that the engineering professional bodies recognise the need for "engaging with sustainable development issues" but that while some progress has been made on environmental aspects "there remained a lack of understanding, and vagueness about sustainability concepts and their implementation into current engineering practice". They argue that what might have traditionally been considered engineering (encapsulated in the language of mathematics) needs now to be balanced with qualitative aspects:

A new pedagogy for dealing with changes from the quantitative to the qualitative is required, as the paper questions where the education balance should lie between providing access to technological knowledge which can be applied to designing hard solutions, and training engineers to rethink their fundamental attitudes towards a broader, multiple perspective approach in which problem formulation and context setting play a vital role in reaching consensual solutions.

They recognise however, that this balancing is not a simple task:

The twin dangers in broadening the remit of engineers, and consequently the range of subjects taught to student engineers, are that the additional topics will be covered, but only cursorily and superficially, and that the technical rigour of the existing courses will be dissipated by the widening of subject matter.

The Accreditation Board for Engineering and Technology (ABET 2007) is a quality assurance body for higher education. They give criteria for programmes in engineering that explicitly includes sustainability under general outcomes (ABET 2007, strangely, the computing document from ABET omits this criteria);

The students in the programme must attain: an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.

Despite this inclusion, Kumar *et al*. (2005) is critical of the ABET approach, primarily because sustainability (along with ethics etc) is seen as a constraint rather than "an underlying principle that serves as a key driver in the design of systems, components and processes". Kumar *et al*. stress an integrated, project based approach:

"the ability to connect and integrate knowledge gained in different areas is not emphasised by ABET"… "to achieve this highest level of intellectual development, students not only need to the knowledge base to make sound engineering decisions, but they need the cognitive and critical thinking skills to supply effective solutions to technical, environmental, and societal problems."

Kumar *et al*. argue that most engineering courses "fail to address" these issues despite "(students in the survey) want sustainability concepts to be institutionalised into the mechanical engineering curriculum". They propose moving beyond technical electives (eg Environmentally Conscious Design), to focus on a vision of integrating a sustainability theme. Key to this is a "redefinition of mechanical engineering to reflect a broader role in benefiting society promoting economic growth and preserving the environment".

Fenner *et al*. (2005) suggest a template for development:

1. Define what is meant by sustainability at the level of engineering operations

2. Challenge the orthodoxy in the traditional problem solving paradigm to refine the problem space to allow for 'messy problems'

3. Encourage both breadth of study and depth of study for more holistically conceived solutions.

This template now underpins engineering at Cambridge. It has meant the introduction of sustainable development thinking into undergraduate teaching; the development of a MPhil in E.ngineering for Sustainable Development; formalising communications on sustainable initiatives; developing sustainable development as a key theme of departmental strategy; and the establishment of a professorial chair in sustainable engineering. They describe the process as "somewhat opportunistic" and "key features of the story including: enthusiastic and pro-active individuals, usually over-committed on time; key seed funding; a practice of "lighting many fires" and of helping existing structures before challenging them".

4.4.3   Business as example

Benn and Bubna-Litic (2003) discussed the changing context of the MBA. They argue that the format of the traditional MBA is one which "celebrates instrumental knowledge which contributes to the maximisation of production", but that this "set of values, however, reflects on a time where the social and environmental consequences of corporate activity were largely ignored… (this is)…reminiscent of 1960s thinking".

They argue that the solution is not to incrementally bolt-on extra papers in environmental management, stating that "shifts that have occurred in the foundation disciplines, however, suggest the need for

second-order changes which affect the very way of knowing and understanding of the discipline".

Benn and Bubna-Litic present two generic strategies: regeneration or generation (of new programmes), both having challenges. They argue that both require a goal of reflexivity with a "greater emphasis on meaning and values, where knowledge is negotiated and where knowledge claims are significant arenas for competition". In concluding with a challenge, they state "the question is not whether it is necessary to make these changes, but how to make them".

BeyondGreyPinStripes (2005) is an initiative to promote sustainability in MBA sustainability education. Business schools participate in a large scale ranking exercise aimed at promoting best practices and identifying exemplars. As part of this they also report on trends in business sustainability education (for example, only 4% of faculty actually published on sustainability related topics).

Zorn and Collins (2006) review the status of sustainable business and Corporate Social Responsibility (CSR- they make a distinction but it doesn't matter here). They conclude that CSR/SB runs counter to traditional business teaching.

Ridener (1999) undertook a pretest/post test study of students completing a course in sustainability. Business students responded less to inclusion of environmental components than other students of other discipline majors (eg non-environmental science students). He suggests that the poor response was due to a lack of critical-constructivist teaching in business and concludes that changes need to go beyond an "environmentalising" of the business curriculum but to include a review of pedagogy.

5 Computing Education for Sustainability

In this section we bring these threads together to explore Computing Education for Sustainability (CEfS). We start by looking for whole programmes (there aren't any), then whole courses, then we look for integrated approaches. These are, by definition, difficult to identify so we look at the extent to which sustainability is integrated into the meta-IT-education: ACM curricula etc, research priorities etc.

5.1 Whole programmes

In preparing this section we made an erroneous assumption: that there would be some programmes in Sustainable Computing. Surely some institution would have a Bachelor's degree in Sustainable Bioinformatics, or in Applied Computing (Environment). But no, or at least we can't find any. The closest we can find are several Geographic Information System degrees, and many Environmental Systems Technology degrees (eg technologies including computing for alternative energies etc).

There are certainly several Masters with a sustainable flavour but these tend to be environmental management programmes with perhaps a leaning to information management or development, or Biotechnology, or Masters of Liberal Arts. Entry criteria do not assume computing (programming etc).

5.2 Whole courses

There are a small number of courses in computing programmes that are explicitly sustainability.

Kurkovsky (2006), for example, described a course on "computational aspects of sustainable development: Sustainable development analysis" as part of an applied computing degree aimed to prepare students for skills needed by the pharmaceutical and health science industries. The course aimed

a) To increase the students' knowledge and understanding of the often complex relationship between sustainable development and the social, economic, and environmental conditions in the world, country or a region of the country; b) To encourage students conducting small research projects within the proposed case studies related to some elements of sustainable development; and c) To improve the students' ability to understand and apply contemporary software for environmental analysis, to decision making, and to problem solving.

The content of the course is examination of existing simulation models: three systems dynamics regional planning simulations, and four air pollution simulations

The BeyondGreyPinstripe (2005) initiative of the World Resources Institute includes a large resource of exemplar syllabi across the full range of MBA courses. This includes computing, mostly sustainability included (or as the basis of) courses in IT management. Most seem to be a standard course in MIS with the addition of a statement to the effect of "…electronic economy…constitutes a new way of conducting business…understanding impact on organisations and industries".

Hufnagel (2004), however, goes further and describes a course that "examines a variety of legal, ethical, and social issues involving information systems and knowledge management techniques, as well as managers' responsibility for ensuring that computing resources are adequately protected and appropriately used. Cases, films, and articles from the business press will be used to highlight contemporary concerns. Class discussion focuses on both the issues involved and possible administrative and technical solutions." The objectives of the course are to:

1. To introduce students to alternative ethical frameworks and develop their skills in applying ethical analysis to problems involving information resource management

2. To develop students' ability to critically evaluate the many legal, ethical, and social issues associated with new and emerging information technologies

3. To increase students' awareness of multicultural perspectives on the appropriate uses of IT and the role technology can/should play in our lives.

Morato (2005), while describing a standard course "to create awareness on the role of Information on Strategic Planning and implementation" goes further than Hufnagel and explicitly aims to "to instil values and attitudes that would refocus students' awareness not so much on technology mastery but technology understanding *vis a vis* communities of practices, social networks, and organizational cultures".

While significant in their inclusion of ethical approaches (and a wider application of these ethics than the usual data security, privacy etc), none of these exemplar programmes, however, come close to considering a full application of sustainability.

5.3   Missing curricula

Despite McGettrick's "crowded curricula", there are some areas of sustainability that, even without transformative change, need to be added to the curricula. This is not an exhaustive list, but computing graduates are currently under-prepared in the following areas:

- Waste management

- Ecolabelling

- Preparation and response to 'green' RFPs

- Energy management

- Carbon management

- Reuse

- Open source (with respect to sustainability arguments)

- Environmental reporting (for themselves and in developing/supporting such systems)

None of these areas need conceptual transformation of programmes.   Some areas are contentious and the approach should be one of critical inquiry.

5.4   Integrated

Fogarty (1991) describes several approaches to integrating a curriculum: "the integrated model views the curriculum through a kaleidoscope: interdisciplinary topics are rearranged around overlapping concepts and emergent patterns and designs".   There are many reports of successful integration of sustainability into school curricula. The *Rethinking School Lunch* programme (Ecoliteracy

2006), for example, combines 10 dimensions including nutrition, exercise, learning and environment.   There are few such programmes at a tertiary level. A notable exception is the information literacy movement (Rockman 2004, Baker and Curry 2004).

Attempting to "infuse sustainability into the curriculum", Down (2006) used introductory computing used as a vehicle for education for sustainable development. In a Caribbean teachers' college, classes on using word-processing software were given a context in a "critically aware framework" – they wrote essays on the roots of violence in Caribbean society.   Computing was chosen as the vehicle for this as it was considered "content open and transdisciplinary".   Unlike a similar course in literature, the computing course did not work: "this is boring", "it's not what we want", "we don't have enough ordinary time with the computers". Down (2006) sees two major reasons for this: student expectations and overzealous teaching.   Students, she says, sign up for courses expecting a particular content, a specific syllabus. When that syllabus or course is modified mid-stream by a lecturer's attempt to reorient that course to engage with sustainability issues, it is likely that there will be some difficulties".

It is perhaps unsurprising that evidence of integrated sustainability is hard to find – by definition it would be in courses and programmes called other things.   We turn our attention to the computing milieu: guiding documents for curricula; statements of ethical principles and research priorities.

5.4.1   Principles of ethical behaviour

The ACM Code of Ethics and Professional Conduct (1992) identifies the "commitment to ethical conduct expected of every member".   It consists of "24 imperatives formulated as statements of personal responsibility". It is argued in the preamble to the code that not every issue is explicitly stated and that the "imperatives are expressed in a general form to emphasise that ethical principles which apply to computer ethics are derived from more general ethical principles".

The first general moral imperative states:

As an ACM member I will …

Contribute to society and human well-being.

This principle concerning the quality of life of all people affirms an obligation to protect fundamental human rights and to respect the diversity of all cultures.   An essential aim of computing professionals is to minimize negative consequences of computing systems, including threats to health and safety. When designing or implementing systems, computing professionals must attempt to ensure that the products of their efforts will be used in socially responsible ways, will meet social needs, and will avoid harmful effects to health and welfare.

The code then continues, covering: avoiding harm to others; being trustworthy; being fair and not discriminating; honouring intellectual property; privacy etc. Beyond these general statements, "more specific professional responsibilities" are stated: striving for excellence; maintaining professional competence; knowing and respecting laws, accepting professional review; giving comprehensive review of computer systems and their impacts including analysis of risks; improving public understanding of computing and its consequences.

Although sustainability is not explicitly mentioned in the code, the precedents for it are. The Software Engineering Code of Ethics and Professional Practice (ACM/IEEE/CS 1999) is more specifically aligned with responsibilities as a software engineer. The code preamble again states its general application

"These obligations are founded in the software engineer's humanity, in special care owed to people affected by the work of software engineers, and the unique elements of the practice of software engineering...The Code is not a simple ethical algorithm that generates ethical decisions"

The SE Code clearly makes reference to wider effects on humanity "consider broadly who is affected by their work; to examine if they and their colleagues are treating other human beings with due respect" and in the first principle "Public" software engineers should "1.03. Approve software only if they have a well-founded belief that it is safe, meets specifications, passes appropriate tests, and does not diminish quality of life, diminish privacy or harm the environment. The ultimate effect of the work should be to the public good...

In addition to a safe social environment, human well-being includes a safe natural environment. Therefore, computing professionals who design and develop systems must be alert to, and make others aware of, any potential damage to the local or global environment.

5.4.2 Curriculum statements

The ACM maintains a series of computing curricula documents (2005) for each of four bodies of knowledge (Computer Science, Information Technology, Computer Engineering and Information Science). Each is a significant document of around 100 pages. Unfortunately there is no mention of sustainability or the environment. Even a wider ethics is only labelled as "other requirements" and somehow sits outside the curricula:

Many institutions have other requirements that apply to all students, such as general education requirements. The size and content of this requirement varies widely, depending on the home country, the institutional mission, legal requirements, and other factors. Such courses often include subjects drawn from the humanities, social sciences, languages, and the liberal arts. In

designing a computer engineering program, attention should be given to utilizing these course requirements to contribute to the students' understanding of the social context of engineering and the potential impact of engineering solutions in a global environment. (Computer Engineering p34).

Some other concepts are described as "pervasive themes"

Several topics have emerged that were considered essential, but that did not seem to belong in a single specific knowledge area or unit. We are of the opinion that these topics are best addressed multiple times in multiple classes, beginning in the IT fundamentals class and woven like threads throughout the tapestry of the IT curriculum. (IT p23)

One such theme is "professionalism (life-long learning, professional development, ethics, responsibility)". An appended matrix identifies courses in which the themes might appear.

There is, however, always a danger that elements of the pervasive themes absorb so much time that they overwhelm the material of the main curriculum. At the same time, these pervasive themes are considered essential for IT students, and must be adequately taught. There are delicate issues of balance here, and curriculum and course designers must find the proper mix. (IT p29)

In summary of these curriculum documents: while general ethics is briefly mentioned, sustainability is not. Although ethics is included as part of a pervasive theme, it is not explicitly included in course descriptors and the advice we receive is that the themes, while essential must not take too much time.

McBride (2006) questions whether computer science is a dying discipline (a subsequent outcry refutes this, see Mander 2006, but his arguments stand). McBride sees relevance of Computer Science courses as the major problem, in essence he says the training is CS but the jobs are IT: "the gap between academia and industry practice is a gaping hole…Implementation, facility management, systems integration, service management, organisational change even environmental audit are the language of IT. These hardly feature on computer science courses."

5.5 Transformation

Software engineering has perhaps already adopted a sustainable approach without explicitly realising it - Agile proponents at least. The language of software engineering is already close to sustainability – stakeholders, interaction, and system requirements – perhaps giving evidence to an extant systems approach.

Tate (2006) dismisses buildings as metaphor for software development as they are largely static and have a clear finishing point. Instead he uses a coral reef metaphor for the software development industry since, like a coral reef, successful software "inhabits a

complex and continually evolving ecosystem…" and "the development team needs to interact with and foster its ecosystem."

A successful software product plays the role of the underlying coral in the reef. The coral is what makes the entire ecosystem possible. None of the other organisms can survive without it. …continually evolving, growing, and changing. The reef is incredibly complex yet also fragile and vulnerable, just as a software product's ecosystem is prone to disruptive technologies or competition. This level of complexity, growth, constant change, evolution, and vulnerability I believe accurately portrays the complex world that today's software products inhabit.

While many Agile references to sustainability derive from a goal of maintaining work pace (through small teams and 40 hour weeks) and long term survival, nevertheless the notion of being aware of the environment in which the industry exists, and the need to nurture that environment, are apparent. By definition, lean methodologies are easier on people, use fewer resources and consider the needs of the stakeholders at every stage of the development and beyond (Boehm, 2004).

Tate describes sustainable development as a pace that can be maintained indefinitely but this does not mean slower development – "quite the opposite", nor a lessening of rigour:

Sustainable development requires a singular focus on a form of technical excellence that regularly provides useful software to customers while keeping the cost of change low…able to deal with change, not be afraid of it or view it as a risk

Tate describes a mindset that the team is in it for the long haul as underlying sustainable development. The team adopts and fosters principles and practices that help them continually increase their efficiency, so that as the project gets larger and more complex and customer demands increase, the team can continue at the same pace while keeping quality high and sanity intact. They do this by continually minimising complexity, re-visiting their plans, and paying attention to the health of their software and its ability to support change.

So, is Sustainable Software truly sustainable? Yes and no. It is clearly a vision of a culture that is informed by sustainability. It does not, though, explicitly describe a culture that is considers the full scope of sustainability (An appreciation of importance of environmental, social, political and economic contexts…etc). One suspects though, that a workplace coming to grips with the ecosystem metaphor and following Tate's advice would be more likely to see the bigger picture.

Blevis (2007) describes a broad approach that brings together computing (HCI) and sustainability in a way that benefits both streams. He argues that sustainability "can and should be a central focus of interaction design". This is works both ways – both from the point of view of how interactive technologies can be used to promote more sustainable behaviours and with a "view of how sustainability can be applied as a critical lens to the design of interactive systems, themselves".

6   Agenda

This paper concludes with a suggested agenda for developing effective CEfS.

Cortese (1999, 2001) stressed the importance of articulating the future.   At present, despite clear calls for all professionals to take a role in sustainable development, computing education is not adequately preparing graduates to meet this need.

McGettrick *et al.* (2005) gives characteristics for a grand challenge.

- Lead to substantial improvement in some significant aspect of the educational processes in computing.

- Arouse curiosity and generate enthusiasm within the computing community.

- Be international in scope and so have wide and significant relevance.

- Have the capacity to bring about changes in attitude, changes in expectation and even change at the social level.

Nicolaides (2006) identifies a number of obstacles but maintains "education for sustainable development is, nonetheless, despite many obstacles, non negotiable". Thomas (2004) similarly identifies barriers in Australian universities with a view to developing strategies to overcome them.   Thomas' barriers include: staff training; a fundamental lack of interest; a lack of tradition; and a lack of priority.

Wright (2007) undertook an exercise aimed at identifying research priorities for higher education sustainability. She found that highly important areas of research included: Impacts of teaching and learning methods: evaluating educational approaches, investigating the role of transformative learning in achieving sustainability, and legitimising sustainability within the discipline:

"while motherhood statements regarding sustainable development are rarely challenged, integrating sustainability into a higher education institution can be very difficult. Examining the perceived barriers and opportunities to incorporating sustainability into curriculum, policy, and operations was considered an interesting and helpful research endeavour. Another research project suggested was the comparison of faculty

perceptions, approaches and integration of sustainability within their specific disciplines"

With this need to identify barriers in mind, we propose items for an agenda for advancing computing education for sustainability.

1. Work with the wider computing community to envisage and articulate a **role for computing and computing professionals in a sustainable future**.

2. Work with the wider computing community to articulate a **discipline response to sustainability**. This may take the form of mission statements (etc) from professional societies.

3. Work with the wider computing community to **describe sustainable behaviours** of computing professionals in sustainability challenges.

4. Develop an **understanding of the current status of sustainability** (values, awareness, knowledge, skills & behaviours) of all our stakeholders (students, intake, stakeholders, staff, graduates, professional/trade connections etc).

5. Identify **sustainable practitioner graduate outcome and core competency** statements for computing. This should be both incremental and transformative.

6. Develop **learning outcomes** integrated into every course looking simultaneously at course specific issues and whole holistic approaches.

7. Identify and promote **exemplar resources and teaching strategies.** As a priority identify **areas missing from current curriculum.**

8. Assess **lecturer expertise** and skill requirements in computing for sustainability and **establish a development plan** for the sector.

9. Integrate sustainability into **quality assurance processes** (curriculum documents, moderation and monitoring checklists etc).

10. Frame **"for sustainability" as a core driver for research**. This means research aimed at increasing the sustainability of computing and enabling sustainable outcomes. Both of these will require much wider and interdisciplinary approach to computing research, and, a move into areas of complex problems.

11. Establish a network of sustainability champions to promote CEfS as a legitimate and mainstream area of computing.

12. Scope CEfS as a **Grand Challenge** in Computing.

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