Sustainability issues in the computing curriculum

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ABSTRACT

"Sustainability" or ("green-ness") has a significant role to play in the teaching of information systems in higher education. There is considerable variation possible in breadth and depth of content, and raises the question of appropriateness, suitability of material and targeting at an appropriate level. There also exists considerable potential for variation of emphasis in presentation according to students' motivations. Institutions have adopted different approaches, some utilising specialised courses as components of wider programmes, or in their own right. Others have integrated the topic into undergraduate teaching, perhaps as a component of systems analysis and design courses, treating environmental impact as a design constraint within a solution. Computer science programmes may use their computer architecture-themed modules to introduce the relationship between hardware design and energy use or the ethics and professionalism strand may be developed through consideration of electronic waste or the legal issues around the need for compliance with legislation.

This paper reports our study of these variations, and introduces some of the teaching materials we have developed as part of a recent HEA ICS project, along with an introduction to a community site to enable colleagues interested in this topic to share ideas and resources.

Keywords

Sustainable Development, Green IT, Society and Computing.

1. INTRODUCTION

The impact of IT and computer systems on the environment is well acknowledged and recognised. Information systems provide an effective framework within which to consider such issues, with its encompassing of topics spanning hardware, software and users. IT can be considered in terms of its running costs – financial and environmental – as well as its potential to alleviate the environmental and financial impact of other activities. From an educational perspective, the expectation – of both accrediting bodies, funding bodies through the subject benchmarks and employers – that graduates are aware of the context of the discipline means in practice that such material should be included in computing courses.

Environmental issues and wider social costs come under the remit of sustainability, in particular within the framework of sustainable development. Sustainable development is generally agreed to be as defined by the Brundtland commission in 1987 "sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." The need to meet the so-called three pillars of SD (environmental, economic and societal) was addressed by the United Nations Conference on Environment and Development (the Rio summit), which developed Agenda 21, which identifies information, integration, and participation as necessary requirement to support SD in a way which also facilitates economic and societal sustainability.

In CS / IS terms, the technology and systems used offer the potential to deliver the agenda 21 requirements: we can develop systems which allow us to gather and integrate information in ways which support education and allow individuals to participate in society.

More precisely, we can develop systems using CS / IS methods which can reduce resource demand (replacing travel with tele-conferencing; saving paper by use of on-line document exchange; developing "smart" energy systems (controlled by IT) which more closely match heating and lighting use to the needs). However, IT is a significant source of demand for resources (most obviously in the form of the electricity it consumes to operate and keep cool, but also in the cost of production and disposal). It is this ability to be both

a solution and the cause of the problem which makes it important to understand the connection between SD and CS hardware and software methods.

Including SD in the CS / IS curriculum offers a number of potential advantages: it has relevance to a very broad range of curriculum topics, from the consideration of hardware and software design, through IT systems design, network deployment, application use and user interaction. The fact that these impacts can be felt at each stage of the lifecycle from initial design through to disposal means that it can be approached in a range of ways, and the general awareness of environmental issues, coupled with potential future employment opportunities, should ensure its relevance to the student.

There now follows a brief consideration of some of the specific drivers for this.

1.1 Employability

There is an expectation [6] that the low carbon economy will generate green jobs. Whilst changes in government and the wider political and financial context alters the emphasis of this, the international framework of carbon taxes, environmental audits and requirements to demonstrate environmental awareness within projects demonstrates that there are new opportunities for roles partially or wholly focussed on sustainability.

Recent research and reports Neil – do we have a ref for this? demonstrate that employers increasingly expect graduates to be aware of, and able to demonstrate skills regarding, sustainability.

1.2 University social and ethical responsibilities

Local – i.e. institutional – aspirations and missions commonly refer to the environment and to sustainability. Whilst frequently focussed more on estates and service costs, many include curriculum and graduate characteristics expectations for an appreciation of social issues. The expectation that these are addressed within curriculum should lead to a corresponding appearance of such topics in programme and module learning outcomes. Indeed, for those interested in promoting such inclusion this provides a potentially effective way through which to entrench sustainability within teaching.

1.3 Professional and benchmark requirements

Within computing, the various relevant professional bodies all have an expectation for contemporary legal, social, ethical and professional content and associated learning outcomes and assessment. Whilst they do not all specify green issues nor sustainability, these topics can provide an appropriate set of examples by which to motivate and contextualise such topics, linking to codes of practice [1] and professional requirements. The professional body most closely associated with computing, the British Computer Society (BCS), has taken the lead in promoting sustainable (or “green”) computing practices, with a specialist group and certification for green IT. The BCS Data Centre Specialist Group also plays a major role in the promotion of energy measurement and reduction techniques for data centres, recognising the fundamental role of data centres in the overall picture of IT sustainability. The Australian Computer Society is also a significant force in raising awareness of sustainable IT practice.

1.4 Student recruitment

Publicising the inclusion of such content can improve student recruitment, as noted by the United Nations [10]. We are 6 years into the United Nation’s “Decade of Education for Sustainable Development”, a recognition that those currently in education have a central role to play in striving towards sustainability. Some institutions utilise this as a major theme and recruitment tool. League tables such as the specific Green League clearly focus on this, while others currently omit this. However, the environmental statement of institutions can influence students’ choice of institution.

2. APPROPRIATENESS OF MATERIAL

When considering the introduction of new material, it should be considered in terms of its appropriateness within the context of the specialism of the degree, of its suitability to the students, and of its appropriateness in terms of level.

Sustainability encompasses a wide range of subthemes [2] – that intersect with a number of aspects of a typical computing course. Material used to raise awareness and understanding of sustainability should refer to these, to ensure it is appropriate to the students own interests [3]. One example within an Information

Systems degree would be that of designing a system to reduce the energy requirements of a system, thereby reducing both the financial and environmental costs, two different subthemes within the sustainability framework. Information Systems provides an effective framework within which to consider sustainability, as explored in [8]. This cross-cutting nature makes sustainability an ideal topic for project work; for example, where the need to address the overall resource requirements of a specific user service calls for the consideration of sustainability across the whole lifecycle; or where the sustainability of a particular process (current or proposed) is assessed.

Motivating and contextualising the content for the students can be most effective when the content is linked to their own interests – and so this can be achieved through the previous approach. Furthermore, demonstrating the practical side – such as more efficient code that is faster, and has less of a storage overheard – can show that there are numerous facets to the issue of sustainability. Another form of motivation is in linking the topic with students' individual professional development. As identified above, employers are increasingly expecting graduates to demonstrate this knowledge, and so one way to motivate is to demonstrate the relevance and benefits of this to students, for example see [5].

When considering the level of material, this is in terms of the complexity and scale of the topic. In a first year undergraduate course, the basic concepts may be addressed and students expected to show an appreciation of the topics. However, within a graduate master's programme there would be an expectation for more critical analysis and even challenging of the issues.

3. EMPHASIS AND MOTIVATION

As identified in the previous section, appropriateness includes motivational factors. Students will usually identify and raise issue with content that seems misplaced or aligned with their other learning. Providing suitable motivation for why something is included, why it is relevant, and how this will impact on students future careers can pre-empt such potential problems. However, placing a suitable emphasis on content can be more challenging and open to individual's own perceptions and views. There are some advantages to emphasizing the pragmatic and objective benefits of an awareness of green information systems [8], which circumvents the arguments around topics such as the evidence of climate change or the need for individuals to concern themselves with long term availability of resources. Of course, such issues are relevant and can be useful examples to explore when considering ethical and professional decisions and behaviours, and may be particularly relevant at the postgraduate level.

4. APPROACHES TO DELIVERY – PLACEMENT

Approaches to the inclusion of sustainability topics vary and there is no ideal solution. The two general approaches are firstly to embed the material within other modules, or secondly to segregate such material to specific modules on sustainability. These are approaches which are used with other topics – employability skills, project management, research skills, numeracy and mathematics to name a few – where delivery can be embedded or separate, and shares the same issues. Embedding can make motivation easier [2], though it can also allow for material to be so embedded and implicit that students fail to identify it or recognise that they have been exposed to it. Conversely, stand-alone modules ensure material is explicit, but can lead to student disengagement and or to them challenging to the relevance. Of course, context setting can be made in the case of standalone modules, but needs to be thought through and kept there as an explicit aim. An entire degree programme can be built around such topics, for example see [7]. Questions of sustainability within computer networking have led to a number of student research topics exploring practical aspects of sustainability such as the data transfer and processing requirements of network management systems; using network management techniques to manage power consumption; the energy use of voice over IP technology; server virtualisation; thin client systems and the delivery of an internal cloud service within the University, supporting teaching, administration and research activities.

5. EXAMPLES OF MATERIAL

As part of a HEA ICS funded development project, a range of materials were developed to demonstrate some of the above approaches and to attempt to address some of the issues. These learning resources encompass a number of topics from within computing, and demonstrate the relevance of sustainability to these. These are envisaged as a set of starting materials, and are available via a Wiki site [9] with the intention that a community of practice develop and that colleagues can share their experiences of using these materials as well as adding new ones or adaptations of the existing ones. These are not the only relevant topics, there are numerous others that can motivate sustainability within computer science – for more examples see [4].

5.1 Hardware and Sustainability

Hardware provides one of the obvious links between sustainable development's environmental theme and computing – hardware has a number of characteristics and issues that make this clearly relevant. These include

- An introduction to Sustainable Development: for those still unfamiliar with this topic, or who would find an introduction helpful for colleagues or students to set the wider context of this, the Wiki includes a learning resource introducing the topic and the main themes that are encompassed by it.
- Power usage: the running power consumption being one aspect of hardware. Selecting more efficient hardware or designing systems that need less infrastructure can reduce the electricity requirements and thereby reduce the carbon footprint of a system. A more complex model of system design would take account of the residual power attributed to a system – i.e. the power used in designing, building, transporting and disposing of it, so that a new Information System design would take account of the environmental cost-benefit of replacing a system with a marginally more efficient one. The Wiki includes a Reusable Learning Object on this topic – with some motivating background and content.
- Social networking, Web 2.0 and Sustainable Societies: one of the themes under sustainability is that of creating sustainable societies. The changes and developments being enabled and encouraged through Web 2.0 are already having significant impacts on global and national societies. This topic can be suitable for modules considering the wider ethical and social impact of computing, and of the ways in which system developers should consider these issues when providing new features. This example illustrates the difficulties faced – because something is feasible there are still decisions to be made about whether to offer that facility, and whether to enable safeguards. Concerns about children on social networking sites, or the impact of these on national legal frameworks such as that around the right to privacy versus freedom of dissemination of information provide real and current illustrations of these tensions.
- Cloud computing and virtualisation: this topic offers a number of points of discussion, beginning with the plethora of suppliers' claims that cloud and virtualisation represent the answer to all matters of sustainability. This allows us to explore with students the need for independent verification and validation of published data, and the need for a common set of measurement and reporting techniques. On a practical level, the skills and techniques required to implement and exploit these technologies allow students to develop understanding of system behaviour and network traffic. Finally, legal and financial awareness can be raised through exploration of the service agreements and cost models used in purchasing cloud resource.
- Web 3.0: while there is dispute about the exact shape and form of Web 3.0, it is clear that it will involve a much greater breadth and depth of interaction, with consequent increased data transfer and storage requirements and an increase in the number and power of web connected devices. From the viewpoint of sustainability, this allows the discussion of the growth and development of technology; and the need for devices to be ever more energy efficient. The probable development of "smart" technology (smart metering, smart homes etc.) offers another perspective, and allows students to explore the concept of greening **by** IT, as a contrast to greening **of** IT. The former is the use of technology to bring about changes in the energy use of organisations, individuals and society; the latter is the reduction of the energy requirements of the information technology itself.
- System Design: opportunities exist across the entire system lifecycle for discussion of sustainability and awareness of factors such as embedded energy (the energy used to construct a piece of equipment); responsible disposal and the possibility offered by virtualisation and cloud computing of replacing physical assets with non-physical ones. This gives rise to a further opportunity to discuss alternative business models which may be needed to support this activity.

6. CONCLUSIONS

This paper has considered some of the issues around sustainability and the computing curriculum, in particular how, where and what could be included under this topic. The examples considered demonstrate the relevance of this, and ways in which such content can be motivated to ensure the explicit links with computing are highlighted and exploited. Whilst an individual's approach to sustainability is an individual choice, the necessity of this awareness in graduates means that there is an imperative to provide exposure to this topic to students within computing courses.

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