Integrating Environmental Issues in IT Education in Tanzania

Matti Tedre, Bukaza Chachage, and Joy Faida
Tumaini University and University of Joensuu

Abstract – **Tanzania is undergoing an unprecedented boom of IT industries. But awareness of environmental issues connected with ICT is almost nonexistent in Tanzania. ICT development without an eye on environmental protection is not sustainable. As of 2009 Tumaini University's B.Sc. program in IT has included a Green Computing course as an obligatory part of IT studies. That course aims at raising students' awareness of environmental issues caused by IT, at giving them knowledge about laws and regulations concerning the issue, and at equipping them with tools and knowledge for making informed choices concerning IT installations. In this paper we analyze Tanzania's educational needs concerning Green Computing and present Tumaini's Green Computing course.**

Index Terms - IT education, environmental issues, green computing, IT curriculum, IT legislation, contextualized IT curriculum

INTRODUCTION

Tumaini University is a private Tanzanian university, consisting of six campuses, the biggest of which is Iringa University College at Iringa town, capital of Iringa region. Iringa is located in a rural and mountainous area 502 km (312 mi) west from Dar es Salaam; the main source of income in the area is agriculture. The college has around 2700 students with a roughly equal male/female ratio. The student profile reflects the variety of cultural backgrounds in sub-Saharan Africa in terms of, e.g., religion, ethnicity, and tribe [19].

Following several years of program planning ([1], [3], [19], [23], [24]), in September 2007 Tumaini University launched a contextualized B.Sc. program in IT (Information Technology). The curriculum was designed to meet the needs of Tanzania, with a focus on the rural Iringa region. The curriculum was based on six principles, which were designed to promote teaching that was context-sensitive, based on problem-solving projects, oriented strongly towards practice and activity, interdisciplinary in design and implementation, of an internationally recognized standard, and based on research [1].

In the course of implementation of the new curriculum, a number of educational aspects needed to be rethought ([21], [22]). Firstly, in a contextualized curriculum the pedagogical approach must resonate with students' and teachers' learning styles. Secondly, the scope of IT education in rural Tanzania must be, in some senses, broader than the scope of IT education in industrialized countries [21]. Thirdly, selection and emphasis of topics must meet the needs of Tanzanian society and Iringa region. Fourthly, a plethora of cultural, technical, environmental, and other contextual issues must be understood and taken into account in curriculum and course design ([21], [22]).

However, although environmental issues were taken into account in program design by teaching students how to protect computing machinery *from* the hostile environment of Tanzania, protection *of* environment was not considered in curriculum design at all. Neither in the design phase of the curriculum, nor in the early phases of the curriculum implementation, did it occur to the program designers and program administration that standards of environmental protection and awareness of environmental conservation issues are seriously lacking in Tanzania. Although Tanzania has nation-wide environmental programs and some education on environmental protection, general awareness of environmental threats caused by computing and communication machinery is almost nonexistent.

Environmental sustainability is not only a function of devices. It is also about consumption culture—about ways of using the device, about chances of re-using it, and about ways of disposing of the device [8]; as well as about the support and regulation mechanisms that a society or manufacturer has put in place. In Tanzania we have never seen, for instance, batteries being collected for responsible reprocessing—instead, we have seen all kinds of batteries, including lead-acid car batteries, being buried at backyards. We have never seen computer and monitor cases being sent for recycling; instead, we have seen broken ICT (Information and Communication Technology) equipment being buried or burned along with other trash—that equipment includes computer and cell phone parts, plastic cases, circuit boards, batteries, and so forth. Similarly, power management, life cycle analysis, recycling, controlled waste disposal, national laws, and international regulations are mostly unknown to ICT users and professionals in Tanzania.

Industrialized countries have, for a long time, recognized the threats of pollution and environmental hazards that ICT machinery cause, and many countries have set up stringent environmental regulations concerning ICT. There are also a number of international conventions and agreements that have an effect on ICT-related waste. Many industrialized countries have effective and efficient recollection and recycling schemes, and often regulations are strictly enforced. Accordingly, there is no shortage of green computing initiatives in industrialized countries (e.g., [25], [27], [28]).

Industrialized countries have initiated various environmental protection projects in Tanzania, but sustainable development cannot be imported from outside—it must start from within. In order to educate our IT students towards responsible development of Tanzania's ICT sector, we decided to add, in our IT curriculum, an obligatory course on environmental issues. For the design of the new green computing course, we brought together three staff members from different faculties of Iringa University College.

This two credit-point course, named "*Green Computing*", is aimed at making students aware of the importance of environmental issues and hazards concerning ICT; at giving them skills and knowledge about how to face those environmental issues and how to reduce or eliminate environmental stress caused by ICT; at familiarizing them with national and international environmental regulations connected with ICT; and at teaching them standard models of waste management. The addition of this obligatory course to Tumaini's IT program is a pioneering move in universities in East Africa, and it strengthens the status of Tumaini's IT program as the most modern and context-sensitive IT program in East Africa.

In this paper we outline the contents and arrangement of our course on green computing. First, we analyze the environmental hazards and environmental issues associated with computing industry; second, we present some of the international, African, and Tanzanian laws and regulations that are related to ICT industry; third, we present our course outline and discuss some of the key ideas we wish to convey to our students in this course; fourth, we finish with conclusions, recommendations, and plans for future work.

HAZARDS AND ISSUES

The number of hazardous substances associated with computing equipment is dizzying. The substances include asbestos, cadmium, hexavalent chromium, lead, organotin, polybrominated biphenyl (PBBs), polybrominated diphenyl ethers (PBDEs), polychlorinated biphenyls (PCBs), polychlorinated dibensodioxins (PCDDs), polychlorinated terphenyls (PCTs), red phosphorus, short chain chlorinated paraffin (SCCPs), arsenic, brominated compounds (including TBBP-A), chlorinated compounds, mercury, phthalates (including DEHP, DBP, BBP, and DINP), brominated flame retardants (BFRs), and sulphuric acid.

The effects of those substances on humans are disastrous. Some of the substances above are carcinogens or mutagens (e.g., Cd, asbestos, Cr(VI), SCCPs, As, PCDDs). Some of them, such as lead, are neurotoxins. Some of them, such as PBBs, cause immune system problems. Some cause birth defects (e.g., PCDDs, pthalates), and all are associated with some health risks. Many of them cause long-lasting damage to the ecosystem—especially damaging are persistent organic pollutants and heavy metals that do not decay or degrade, but bioaccumulate and biomagnify (e.g., organotin, PBDEs, SCCPs, mercury, arsenic, cadmium). If not disposed properly, many liquid or water-soluble substances slowly percolate down through the soil strata to the groundwater, contaminating the soil and/or the groundwater (e.g., As, sulphuric acid).

The whole production and life span of computing equipment is much longer than students usually perceive it to be (see Figure 1). The life span starts from producing the basic materials—for instance, producing metals usually requires blasting ore out of rock, extracting it with toxic chemicals, smelting it in blazing furnaces, and refining it [25]. All around Africa, including Tanzania, there are examples of serious pollution and deforestation due to the mining industry [31]. The process continues with transportation to manufacturing sites and assembly sites, packaging, shipping, and selling [25]. Most of those steps are highly energy-intensive [16]. Only after this process begins the life span that IT professionals usually perceive (Figure 1). Note, however, that in Figure 1 the most heavily polluting parts of the life span of computing equipment usually take place in the developing world, whereas the most economically productive parts take place in the industrialized world.

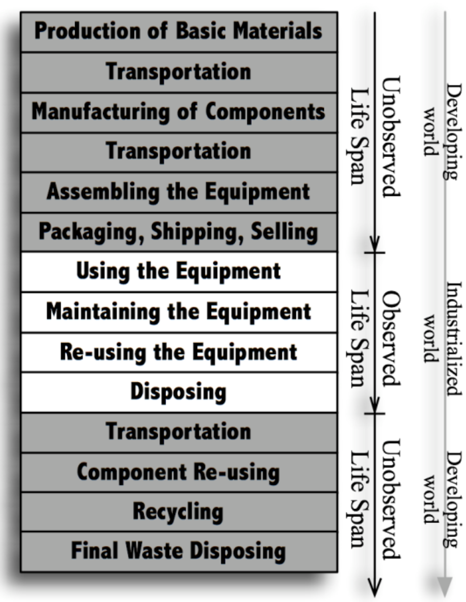

FIGURE 1: LIFE SPAN OF ICT EQUIPMENT

But when the usually perceived life cycle of computing equipment ends, equipment still has a long way to go: it goes for component re-use, recycling, and finally for final waste disposal. Alas, computing equipment rarely gets a dignified end in a proper recycling plant, but often the last stretch of equipment life takes place in developing countries where regulation is lax or non-existent. China and West Africa have the most alarming examples of irresponsible e-waste "recycling". The methods are crude: poor people from peasant background burn, in the open air, computers, wires, and equipment to get rid of the plastic covers, and then sift through the pile of ash to collect metals [32]. Needless to say, the fumes and ash are highly toxic ([14], [32]). The same people use coal grills to release valuable chips from circuit boards, and burn residual useless plastics or dump it in the nature, rice fields, irrigation canals, or waterways [32]. Chinese researchers who studied the Guiyu area in China reported: "*These extremely hazardous and dangerous E-waste "recycling" operations render the air, water and soil of Guiyu heavily polluted, which also poses a threat to the health of workers and local residents*" [32].

The "recycling" of e-waste in Guiyu has polluted the area so thoroughly that drinking water is brought in from 30 kilometers away, as the water near the open burning sites contains lead 190 times over the WHO (World Health Organization) lead threshold [32]. The high lead levels affect the development of the central nervous system and IQ (Intelligence Quotient) of young children in the area, and the area has unusually high levels of skin damage, headaches, vertigo, nausea, chronic gastritis, and gastric and duodenal ulcers [32]. In another study, researchers found out that compared to a non e-waste site 30 kilometers away from Guiyu, the road dust in Guiyu area had 371 times higher concentration of lead and 155 times higher concentration of copper [14]. In Africa, the Lagos port in Nigeria has been claimed to receive 500 containers of used computing equipment per month [7], and there are similar "recycling" operations as in Guiyu. Our students must understand the destructive consequences of uncontrolled e-waste disposal.

LAWS AND REGULATIONS

The concept *sustainable development* was defined in the famous Brundtland Report of the World Commission on Environment and Development (WCED) two decades back, as "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*" [29]. At the core of this notion is the element of conciliation between the natural environment and economic growth [3]. Any economic development policy that ignores environmental consideration fails the test of sustainable development [3]. In a similar manner, sustainable ICT development takes into account environmental considerations. There are a good number of international, regional, and national regulations on hazardous waste in place, and in our green computing course we discuss a number of central ones.

International and Regional Conventions

In Tanzania neglect of environmental issues is, above all, a sociocultural and economic issue. One of the effective ways of addressing social concerns in Tanzania is through adoption and enforcement of policies and legislation. Most of the western world has already responded to the issue of e-waste via legislation. In Tanzania the relevant conventions regulating hazardous waste are the Basel Convention on the Control of Transboundary Movement of Hazardous Waste and their Disposal, and the Bamako Convention on the Ban of the Import into Africa and the Control of Transboundary Movement of Hazardous Wastes into Africa. While Basel is a global convention, Bamako is limited to Africa.

The Basel Convention [12] was adopted in 1989, and it is aimed at regulating transboundary movement of hazardous waste. There are a number of important provisions in the Basel Convention. The convention aims, among other things, at minimizing international trade on hazardous waste; at demanding that such waste cannot leave the exporting country without written consent of the importing country; and at requiring that international standards are followed on packaging, labeling, and transporting hazardous waste ([12], Art 4.2 (a/d), Art 4.1 (c), Art 4.7 (b)).

But having the regulations in place is not enough. The Basel Convention has been criticized on grounds that rather than ban the trade of hazardous waste, including e-waste, it only regulates the trade, thus inadvertently promoting it [5]. Other grounds on criticism include the convention's failure to make provision for stopping shipment that has not obtained prior consent from the importing state authorities; vague definitions of key terms such as "hazardous waste" and "environmentally sound"; and the fact that the convention permits bilateral waste trade [5].

What is more, many industrialized nations, including the largest producers of e-waste, have not ratified the Basel Convention, and many industrialized countries even make it to the Basel Hall of Shame for actively undermining the Basel Convention's aim of ending dumping of hazardous wastes from rich to poorer nations (www.basel.int). The term "re-use" has effectively become a pretext for exporting junk that is essentially waste. The Basel Action Network found that 75% of computing equipment, which was brought to Nigeria for "re-use", was strictly e-waste, beyond reparation by even excellent electronic engineers [3]. Additionally, a large percentage of functioning computers donated to developing countries are already outdated at the moment of "donation", hence attributing to nothing more than waste dumping. Also our university has received proposals for "donating" obsolete computers, as if the African magic would breathe new life into them.

The Bamako Convention was adopted by 51 African countries in Bamako, Mali, in 1991. One of the major motivations was the fact that African countries considered the Basel Convention inadequate and wanted to ban the import of hazardous waste into Africa [12]. In addition, this convention was aimed at introducing preventive measures and at guaranteeing appropriate disposal of hazardous waste. The provisions of the Bamako Convention largely mirror those of the Basel, with some differences. An important difference is that the Bamako Convention criminalizes import of hazardous waste into Africa from outside the region and from non-contracting parties (Art 4.1) [12]. The convention also prohibits dumping hazardous waste at sea as well as incinerating it (Art 4.3 (b)) [12]. Tanzania ratified Bamako Convention in 1993.

National Regulations

At national level in Tanzania, the main legislation pertaining to environmental governance is the *Environmental Management Act*, No.20 of 2004. Section (e) under part IX of this act specifically addresses management of hazardous waste. The provisions dealing with hazardous waste largely regulate movement of this waste. Under section 135, subsection 3, those who generate hazardous waste are responsible for its disposal. The subsequent section alludes to the fact that hazardous waste may be deposited into soil, air, or water. But there is an apparent deficiency in this legislation as far as e-waste is concerned. Compared, for instance, to the EU regulations [6], there is a need to enact more specific regulations that will comprehensively address management and disposal of e-waste in Tanzania.

Like many other African countries, in Tanzania the current legal and regulatory framework is deficient. Not much has been done in the area of e-waste management or other issues of ICT-related pollution. As future professionals, IT students have the potential to contribute towards the development and enactment of the relevant legislation in this area. Similarly, as technical experts, IT students have the potential to review any existing laws and make relevant suggestions for amendments. Being aware of the issues and threats, the future ICT experts have the potential to invent new ways of addressing ecological and environmental issues—ways that are conducive to the third world situation. To introduce ICT and simply encourage its use as purely beneficial—without pointing out the costs associated with its use—would be deceptive. Morally speaking, it is important that ICT is embraced in an open manner—in a manner that openly criticizes its negative aspects and seeks ways of improving its benefits.

COURSE OUTLINE

This course has some main aims. First and foremost, this course is aimed at making students aware of the seriousness of ICT-related pollution and ICT-induced stress to the environment. Second, students learn to understand the environmental effects of computing installations, and to weigh the trade-offs between those effects [9]. We would like to instill in our students the attitude that environmental issues are all about small choices that they can make, and we would like to give them knowledge and mental tools to do the right choices. Finally, we wish to give our students a good overall understanding of legislation—which functions as another tool for environmental protection.

Although for us this course seems like an obvious part of any sustainable and responsible computing curriculum, the course seems to be a rare one, especially as an obligatory IT course. The model curricula of Association for Computing Machinery (ACM) and Institute for Electrical and Electronic Engineers' Computer Society (IEEE-CS) do not deal with environmental issues. The model curriculum of ACM's special interest group for IT education (SIGITE) does not mention environmental issues at all [18]. Neither the IEEE/ACM computer science model curriculum from 2001 nor the IEEE/ACM computer engineering model curriculum from 2004 mention environmental issues even under the "risks and liabilities" section of social and professional issues ([10], [11]). It seems that the computing community has only lately come to realize or acknowledge the environmental risks of computing industry and the environmental responsibilities of computing professionals. In other technical fields such issues are a part of standard technological literacy (e.g., [9], 65–72). As a web search finds a number of green computing courses around the world, it seems that the situation is changing.

Course Topics

We have divided our course into 6 topics that span over 15 weeks. Those topics are portrayed in Figure 2. In addition, Figure 2 shows the weekly topics in the course.

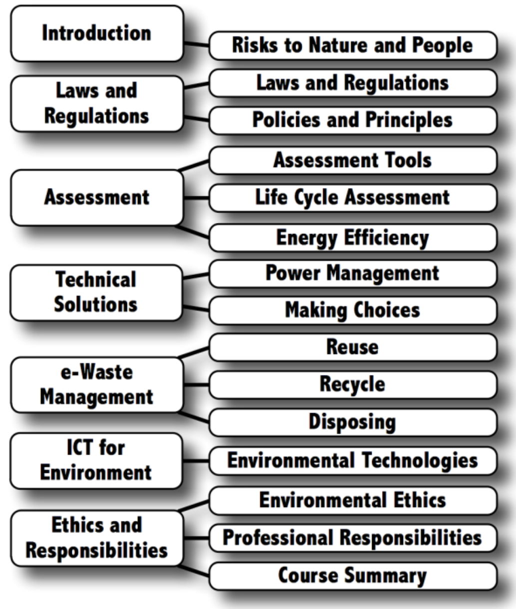

FIGURE 2: COURSE OUTLINE

Our environmental technology course starts with an introduction to general environmental issues concerning information and communication technology. We have made the introduction to this course a shocking one so as to make students understand the seriousness of environmental issues to the future of Tanzania. We talk about the environmental issues related to manufacturing and shipping computing technology, including the exploitation of African resources and the environmental disasters that have resulted from reckless mining and refining industries that produce material for electronics components manufacturers. We talk about the hazardous materials that e-waste contains and about the effects of those materials on people. Concerning this topic, students do a small survey on habits that local people have in disposal of electronic equipment, they analyze the risks that those habits bear, and they think about ways of educating the public about e-waste concerns.

After the introduction, as the second topic, we proceed to talk about different international and national laws and regulations and proceed with a small practice study about environmental awareness in Iringa. Here we contrast the regulations of many EU countries and U.S. states with the Tanzanian and African regulations. We introduce students to ideas like Polluter Pays Principle (PPP), Extended Producer Responsibility (EPR), Integrated Product Policy (IPP) and take back-systems. Concerning this topic, students discuss, in small groups, the problems of differing regulations, and suggest solutions for that problem.

Third, we introduce students to a number of environmental assessment tools. The environmental assessment tools to be highlighted in this course are Strategic Environment Assessment (SEA), which deals with policies and programs; Environmental Impact Assessment (EIA) for planned computer activities; Material Intensity Per Unit Service (MIPS), which deals with how much materials are used and size of the ecological rucksack of computers; Ecological Footprint Risk Assessment, which assesses dose response and risk characterization; and Energy Star's assessment system (www.energystar.gov).

In addition, this course acquaints students with Life Cycle Assessment (LCA) methods. Using LCA students learn how to analyze emissions from the point of manufacturing to the point of disposing. The assessment is done at each phase of equipment life span. It starts with mining the raw materials, manufacturing of the computers and its related products, packaging of computers, transporting computer equipment to the market, energy use of computer during their operation, and energy required for recycling and disposing. Concerning this topic, students work in small groups to select and use one of the analysis tools above, and conduct a small analysis of a hypothetical computer installation in rural Tanzania. Each group reports their analysis and submits the results for the whole class for deliberation.

Our fourth topic has two subtopics. We talk about energy efficiency—a very topical issue in sub-Saharan Africa where there is acute shortage of electric power. Although 100% of Tanzania's national grid power is hydroelectric power, the growing needs are already now straining the capacity. We begin with fundamentals of energy efficiency by teaching students how to identify those parts of computing systems that consume the most energy; for this purpose we use Sankey Diagrams and other similar tools. We discuss different green computing initiatives that aim at energy efficiency, ACPI (Advanced Configuration and Power Interface) power management (www.acpi.info), and cooling [17]. We note the significant economic savings per year—up to $75 per computer—from taking energy saving measures on desktop computers [27], and we teach students to measure and calculate such savings.

In the context of technical solutions, we talk about simple ways of harnessing green ICT [15], such as unplugging equipment that is not in use, choosing energy-efficient components, virtualization techniques, eliminating phantom loads, and using technical and psychological means to minimize needless printing and maximize efficiency of using resources ([20], [27]). Students learn how to measure energy consumption using cheap measuring equipment, they learn how to calculate costs associated with computer use and phantom load, and they compare laptop vs. desktop power consumption as well as CRT (Cathode Ray Tube) monitor vs. TFT (Thin-film Transistor) monitor power consumption [20]. Students undertake a project where they measure the power consumption of different kinds of computer set-ups, and calculate the power and cost savings of energy-efficient hardware on the scales of one workstation, one small company, one large company, and national scale.

Our fifth topic in the course is management of electronic waste. First, we discuss and broadly define the concept of e-waste. Computers and mobile phones create a difficult disposal problem because they contain large quantities of toxic materials and because their life span is short [30]. In addition, only a fraction of computers and mobile phones is reused or recycled—most are dumped on landfills [30]. Thereafter, we classify different kinds of e-waste and locate them in the waste management pyramid that consists of strategies for avoiding creation of waste, reuse strategies, recycling options, disposing to landfills, and means of incineration. We discuss the intricacies of those layers of the waste management pyramid. We discuss ways of making e-waste management profitable [13]. We include a topic on disposal, storage, and transportation of computer hazardous wastes; that topic is of utmost importance in rural Tanzania, as hazardous waste may need to be stored for long periods of time before there is a possibility for sending it for proper reuse or recycling. Students undertake a small project where they analyze the regional needs for e-waste management, and develop a regional strategy for management of e-waste.

As our sixth topic we introduce students to technologies that are aimed at environmental sustainability [28]. We familiarize students with technology such as sensor networks for monitoring conditions of environmentally sensitive areas [26], how ICT can be used to green other industries [1], and how smart homes can bring significant energy savings [25].

As the last topic, the course covers ethics and responsibilities. We discuss environmental ethics and the rights and responsibilities of IT professionals. We attempt to spark the students' awareness of their global, societal, and ecological responsibilities as IT professionals. And finally we lead the students back to think about how they should act so that no country or area is turned into e-waste badlands.

CONCLUSIONS

IT education in developing countries faces challenges different from the challenges of IT education in industrialized countries. One of those challenges is the acute lack of knowledge about environmental issues among the general public and among IT students. But it is computing professionals who, in the end, make the decisions about what kind of equipment is used, how its life span is designed and implemented, and what happens to the equipment after it becomes obsolete or breaks.

We have answered this issue by including, in our IT curriculum, an obligatory course on green computing—a course that is absent from the standard IT curricula and that is rare in computing curricula around the world. Although the name "*Green Computing*" has a slightly fad-like transitory ring, environmental concerns of technology endure. By offering students knowledge that is vital to the future of Iringa region and Tanzania, this course supports Tumaini University's unique contextualized viewpoint to IT education.

ACKNOWLEDGMENTS

In addition to Tumaini University's Office of Research and Publications, this research was supported by Academy of Finland grant 128577, "*Improving the Contextual Impact of ICT Education in Southern Tanzania: Engaging Stakeholders Towards Innovation*," led by Prof. Erkki Sutinen, University of Joensuu, Finland (2009-2012). Our research group i4d.Tanzania (http://www.info4d.org/) has also received funding from Kauppaneuvos Otto Malmin Lahjoitusrahasto (2008). We wish to thank Ms. Sunna Kovanen for impetus for developing this course.

REFERENCES

[1] Aronson, J. S., "Making IT a Positive Force in Environmental Change", *IT Professional*, *10*, 1, 2008, 43–45.

[2] Bangu, N., Haapakorpi, R., Lund, H. H., Myller, N., Ngumbuke, F., Sutinen, E., & Vesisenaho, M., "Information Technology Degree Curriculum in Tanzanian Context", *Proceedings of the IST-Africa 2007 Conference*, (Eds. P. Cunningham & M. Cunningham), Maputo, Mozambique, May 9–May 11, 2007, CDROM.

[3] Basel Action Network, "Turn Back the Toxic Tide", *Briefing Paper 10*, June 2008.

[4] Birnie, P. & Boyle, A., *International Law and the Environment*, 2nd ed., Oxford, UK: Oxford University Press, 2002.

[5] Clapp, J., "The Toxic Waste Trade with Less-Industrialised Countries: Economic Linkages and Political Alliances", *The Third World Quarterly*, *15*, 3, 1994, 505–518.

[6] European Union, *Directive 2002/96/EC of the European Parliament and of the Council of 27 January 2003 on Waste Electrical and Electronic Equipment*, 2003.

[7] Grier, D. A., "Click Here to Empty Trash", *IEEE Computer*, *41*, 9, 2009, 6–8.

[8] Huang, E. M., Yatani, K., Truong, K. N., Kientz, J.A. & Patel, S.N., "Understanding Mobile Phone Situated Sustainability: The Influence of Local Constraints and Practices on Transferability", *Pervasive Computing*, *8*, 1, 2009, 46–53.

[9] International Technology Education Association, *Standards for Technological Literacy: Content for the Study of Technology*, 3rd ed., 2007.

[10] Joint Task Force on Computing Curricula, *Computer Curricula 2001: Computer Science*, IEEE Computer Society and Association for Computing Machinery, 2001.

[11] Joint Task Force on Computing Curricula, *Computer Engineering 2004: Curriculum Guidelines for Undergraduate Degree Programs in Computer Engineering*, IEEE Computer Society and Association for Computing Machinery, 2004.

[12] Kiss, A. & Shelton, D., *International Environmental Law*, 3rd ed., Ardsley, NY, USA, Transnational Publishers Inc, 2004.

[13] Krikke, J., "Recycling e-Waste: The Sky Is the Limit", *IT Professional*, *10*, 1, 2008, 50–55.

[14] Leung, A. O. W., Duzgoren-Aydin, N. S., Cheung, K. C. & Wong, M. H., "Heavy Metals Concentrations of Surface Dust from e-Waste Recycling and Its Human Health Implications in Southeast China", *Environmental Science & Technology, 42*, 7, 2008, 2674–2680.

[15] Murugesan, S., "Harnessing Green IT: Principles and Practices", *IT Professional*, *10*, 1, 2008, 24–33.

[16] Oliver, J. Y., Amirtharajah, R., Akella, V., Geyer, R. & Chong, F. T., "Life Cycle Aware Computing: Reusing Silicon Technology", *IEEE Computer*, *40*, 12, 2007, 56–61.

[17] Przybyla, D. & Pegah, M., "Dealing with the Veiled Devil: Eco-Responsible Computing Strategy", *Proceedings of the 35th Annual ACM SIGUCCS Conference on User Services*, Orlando, Florida, USA, 2007, 296–301.

[18] SIGITE Curriculum Committee, *IT 2005 Model Curriculum Report*, October 2005. Retrieved from http://www.acm.org/education/curric_vols/IT_October_2005.pdf

[19] Sutinen, E. & Vesisenaho, M., "Ethnocomputing in Tanzania: Design and Analysis of a Contextualized ICT Course", *Research and Practice in Technology Enhanced Learning*, *1*, 3, 2006, 239–267.

[20] Talebi, M. & Way, T., "Methods, Metrics and Motivation for a Green Computer Science Program", *Proceedings Of The 40th ACM Technical Symposium On Computer Science Education*, Chattanooga, TN, USA, 2009, 362–366.

[21] Tedre, M., Bangu, N., & Nyagava, S. I., "Contextualized IT Education in Tanzania: Beyond Standard IT Curricula", *Journal of Information Technology Education*, *8*, 1, 2009, 101-124.

[22] Tedre, M., Sutinen, E., Ngumbuke, F. D. & Bangu, N., "Implementing a Contextualized IT Curriculum: Ambitions and Ambiguities", Presented at the *8th Koli Calling International Conference on Computing Education Research*, Lieksa, Finland, November 17-20, 2008.

[23] Vesisenaho, M., *Developing University-Level Introductory ICT Education in Tanzania: A Contextualized Approach*, Joensuu, Finland, University of Joensuu Press, 2007.

[24] Vesisenaho, M., Kemppainen, J., Islas Sedano, C., Tedre, M. & Sutinen, E., "Contextualizing ICT in Africa: The Development of the CATI model in Tanzanian Higher Education", *African Journal of Information and Communication Technology*, *2*, 2, 2006, 88–109.

[25] Want, R., "How Green Is Green?", *Pervasive Computing*, *8*, 1, 2009, 2–4.

[26] Wark, T., Crossman, C., Valencia, P., Swain, D., Bishop-Hurley, G. & Handcock, R., "Sensor and Actuator Networks: Protecting Environmentally Sensitive Areas", *Pervasive Computing*, *8*, 1, 2009, 30–36.

[27] Wilbanks, L., "Green: My Favorite Color", *IT Professional*, *10*, 6, 2008, 64.

[28] Woodruff, A. & Mankoff, J., "Environmental Sustainability", *Pervasive Computing*, *8*, 1, 2009, 18–21.

[29] World Commission on Environment and Development, *Our Common Future*, Oxford, UK, Oxford University Press, 1987.

[30] World Watch Institute, *State of the World 2000*, W. W. Norton & Company, New York, NY, USA, 2000.

[31] Yager, T. R., Bermúdez-Lugo, O., Mobbs, P. M., Newman, H. R. & Wilburn, D. R., "The Mineral Industries of Africa", *2005 Minerals Yearbook: Africa*, U.S. Department of the Interior and U.S. Geological Survey, 2007, 1.1–1.25.

[32] Yu, X. Z., Gao, Y., Wu, S. C., Zhang, H. B., Cheung, K. C. & Wong, M. H., "Distribution of Polycyclic Aromatic Hydrocarbons in Soils at Guiyu Area of China, Affected by Recycling of Electronic Waste Using Primitive Technologies", *Chemosphere*, *65*, 9, 2006, 1500–1509.

AUTHOR INFORMATION

Matti Tedre, Ph.D., Assistant Professor (yliassistentti) at University of Joensuu, Finland; Associate Professor and Head of B.Sc. Program in IT at Tumaini University – Iringa University College, Tanzania, firstname.lastname@acm.org.

Bukaza Chachage, Ph.D., M.Sc. in Environmental Management, Lecturer at Faculty of Business and Economics; Director of Research, Publication, and Postgraduate Studies, Tumaini University – Iringa University College, Tanzania, firstname.lastname@tumaini.ac.tz.

Joy Faida, LLM., Lecturer of Environmental Law at Faculty of Law, Tumaini University – Iringa University College, Tanzania, firstname.lastname@tumaini.ac.tz.