



I.T Dumping in Africa: How Green Technology Can Be an Antidote

Yongho Shiwoh Louis*

University of Bamenda, Bamenda, 00237, Cameroon

Email: yongholouis@gmail.com

Abstract

Man's negative impact on the environment due to various activities has raised serious concerns with numerous campaigns rising to protect the environment. Computer waste also contributes to damaging not only the environment, but has serious consequences on human health resulting from pollution of the air, water and soil which are part of the ecosystem. With E-waste causing such problems and a challenge to developing nations which have been dumping grounds, the need to adopt green information technology [IT] is becoming more evident. In this paper, we recommend adoption of green IT education by schools, governments, organisations producing or shipping IT products and individuals consuming these technologies to work together in adopting green IT to reduce E-waste accumulation and hence eliminate the environmental and health implications of E-waste.

Keywords: Africa; Green Technology; E-waste; Digital Divide; developing countries, Knowledge Society.

1. E-waste: the challenge of green technology

E-waste has been formally defined elsewhere [21; 43]. It covers the range of items from fridges, to VCR, TVs, Obsolete Media, Computers and Phones that have become old, broken, beyond economic viability or obsolete and require the effort of safe disposal. It is also covered by international agreements of movement and disposal of E-waste. Electronic waste or E-waste is the most rapidly growing waste problem in the world [2; 43].

* Corresponding author.

Noted also is that E-waste problems are often exported from Developed Countries to Developing Countries, an issue we shall return to [33]. Many will no doubt possess old machines that still meet the functional requirements say to author this document. Nonetheless there is clearly an obsession to have the very latest in technology. As an illustration consider how CRT TV and Computer Monitors – the norm for many years, and a big breakthrough when compared to cards or teleprinters – are now replaced by flat screened displays for all our latest usages [51]. This leads us to the problem of having a large quantity of redundant CRTs to deal with, with associated problems caused by nature of a vacuum tube and its contents (cadmium, lead/barium). Touch screens may well do the same to ordinary flat panels and as a result, the problem grows and compounds.

Although E-waste has negative consequences on both human health and the environment, the amount of such waste generated each year seems to be on the rise. Greenpeace International, citing the UN, reveals that about 20-50 million tonnes of E-waste are generated worldwide every year [10]. Mindful of the consequences, the European Community has a good environmental policy to preserve, protect and improve the quality of the environment as they seek to protect human health and has thus set some directives on waste electrical and electronic equipments (WEEE). The EU Directive 2002/95/EC restricts the use of hazardous substances in electrical and electronic equipments while encouraging these equipments to be recycled [20]. EU legislation also encourages replacement of heavy metals (e.g. Lead, Mercury, Cadmium) with safer alternatives. Such metals have grave consequences on human health when they are broken down in the environment and hence the need to completely replace them with safer alternatives.

We intend in this paper to focus on how Green IT provides a potential way to tackle some aspects of this problem and specifically highlights the role of education. In doing so we explore how new (learning) technologies like the Semantic Web [5], Personalised Web Services and Web 2.0 Communication Technologies might contribute to a solution within the context of an emerging Knowledge Society. We will reflect on the roles other agencies like government, NGOs, and individuals can play. We noted earlier the issues of the drift of E-waste problems to developing countries – we will use Africa as a case study in this paper.

1.1. Background in Context

Poverty, disease and malnutrition have characterised some developing nations, including those in sub-Saharan Africa, for several years. Although much effort has been made to improve the situation, the consequences of this “terrible trinity” still haunt most of sub-Saharan Africa which have very frail economies. The high level of poverty and unemployment forces citizens to fend for themselves through different forms of entrepreneurship, some of which are dangerous to their health and wellbeing such as burning E-waste to obtain and sell copper and other metals [1; 2-3]. The advent of information and communication technologies (ICTs) has brought about new hopes for a better life not only for those in developed nations, but also for many people in the developing world. The world is now much more interlinked through shared information with an increasing need for global online connection using computers. The challenge however for African nations has been to procure, employ and exploit these technologies to run various sectors of the society in order not to be left out of this information revolution and Knowledge Society in the same way they did not benefit from the industrial revolution.

It is now common to see many internet cafés dotted all over cities as the young and old alike flock in to learn this technology and to communicate with the outside world. These ICTs at the end of their lives become E-waste which would need to be recycled. Nevertheless, lack of adequate recycling facilities and hence poor management and non-adoption of green computing practices has given more negative inputs into the poverty-disease -malnutrition cycle, resulting in grave environmental and human health consequences. As much of the E-waste is not properly recycled, some individuals, in order to get wealth out of the waste, resort to sorting out some useful components which could be sold [46]. Much of these wastes come from used and cheap computers, purchased from the West [mainly Europe] to help close the digital gap in Africa.

2. The digital divide in africa

The use of information and communication technologies to drive many sectors of the community worldwide has resulted in an increased demand for these technologies. Consequently, production has been on the rise. Shipping of computers to Africa has also risen, with Computer Aid International having shipped over 5000 PCs to Ethiopia for educational organisations [11]. The lifespan of these computers are usually very short given that they are mostly refurbished computers from previous use abroad leading to these African countries being a dumping ground for old machines.

Although there is an increase in the number of computers in use, there is still an inequality in their availability in some parts of the world, with developed countries having more access than developing countries. In 2009 for instance, there were on average 5 learners per computer in the United Kingdom, with the BBC earlier reporting the existence of a computer in more than half of all households in the UK [3]; whereas in 2009, there were 117 learners per computer in Ghana [27-28]. This shortage of computers in Sub-Saharan Africa could be due to the fact that most people cannot afford to own a personal computer due to poverty. This shortage is also matched by very low broadband subscriptions with 1 fixed broadband subscriber for every 1,000 people in Africa compared to 200 subscribers per 1,000 people in Europe [29]. The ITU blames low usage of broadband in Africa on poverty and high prices [27, 28]. This inequality in the possession and use of information and communication technology in Africa has resulted in a digital divide [24]. The digital divide in Africa is further subdivided in a secondary level due to an imbalance in ICTs between urban and rural areas as is the case with Tanzania [24] and throughout the continent. The urban areas are often prioritised in developmental projects to the detriment of rural areas [37]. At a tertiary level, there is a digital divide between people without disabilities and those with disabilities [37; 48] as most of the computers purchased do not come with appropriate assistive technologies for people with disabilities, excluding most of them from using these technologies.

Although there is a wide digital gap in the acquisition and use of computers, the story is different for mobile phone penetration which has grown steadily over the years with several countries in sub-Saharan Africa having levels of mobile phone penetration eight times higher than fixed-line penetration [32]. Mobile phones have thus replaced landlines as the main means of communication, but could also be used to educate the population on the importance of Green IT and the E-waste problem. Text messages could be used for pedagogic purposes without the need to generate paper waste from information leaflets. The access of the internet via Mobile Phones in some way mitigates the lack of typically fiber-based broadband and does so using existing connectivity –

without the need for extra network access or additional technology. Despite the efforts that have been made to close the digital gap, this divide still continues, demanding much effort to tackle some of the indirect consequences that are not readily visible except through critical lenses. We will scrutinise these consequences in the following sections and explore some solutions.

3. Social consequences of the digital divide

Most computer importers in Africa do not have a plan for recycling these computers; consequently they are being dumped in fields as E-waste with some serious environmental and health consequences (Figure 1) which will be examined below.

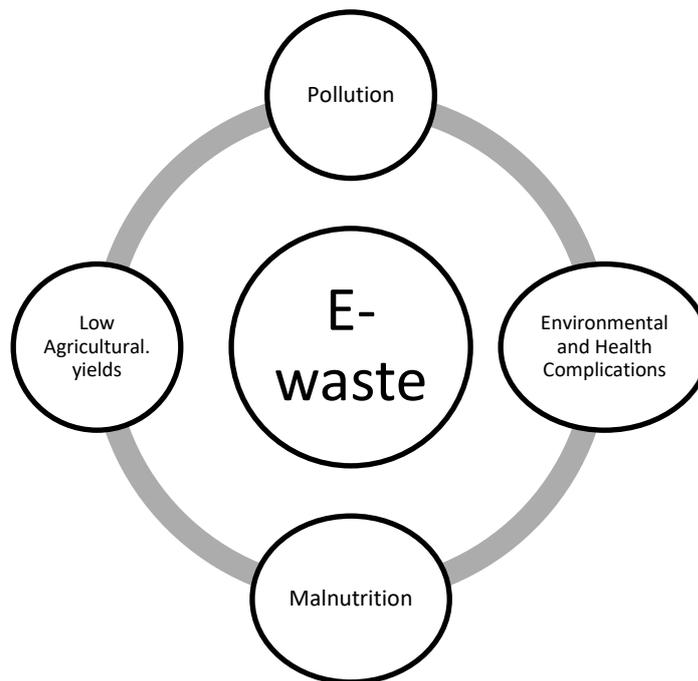


Figure 1: The consequences of E-waste

3.1 Importation of Cheaper Computers

To deal with the massive deficit in computers in most African economies, businessmen have resorted to cheaper computers. Often the cheaper options are computers which have reached the end of their lives but have been refurbished and sold at a cheaper rate as second-hand computers [39]. The main source of such business has been through non-governmental organisations in the West; such as Computer Aid International and Digital Links in the UK as well as other organisations in the USA and other countries in the North. Because these computers are refurbished, they might not last much longer and would need to be discarded after a few years of use. Many of the countries in Africa who are recipients of used computers lack proper disposal facilities, leading to E-waste accumulation.

3.2 E-waste Accumulation

It is rather unfortunate that most African countries are not equipped with recycling facilities [46] for electronic waste which typically end up in fields and are burnt. E-waste in Africa is made up of computers and their accessories, radio, mobile phone parts and other electronics. Problems with E-waste management have also been reported in Taiwan [35] and Peru [30].

3.2.1 Environmental Consequences

E-waste is usually poorly handled by the local population who have not been educated on their consequences. Poor handling includes burning such waste in the open, with the fumes being released into the atmosphere and with some of the hot waste sinking into the soil, with grave human and environmental health consequences (Figure 1). Most economies in Africa rely on agriculture but some are often plagued with drought and hence a poor harvest. E-waste components such as cadmium can contaminate the soil and inhibit plant growth [31], not only leading to poor yields but also potential health difficulties such as cancer [36]. Some of the heavy metals released from E-waste are unsuitable for agriculture, further compounding the problem of drought and poor yield which could mean the population would have less food for consumption and hence malnutrition. This cycle could be broken by reasonable behaviour and adoption of policies that would completely stop or reduce the release of E-waste into the environment.

3.2.2 Consequences on Human Health

There is no doubt that when the environment is polluted, this has negative consequences on human health. As humans are part of the ecosystem and feed on plants and other animals as well as drink water, and inhale air from the atmosphere, the pollution of these sources are bound to impact negatively on human health. Computer electronics are a big source of E-waste in developing countries, usually in varying concentrations, but with hazardous effects. The lead concentration in printed wire boards for instance has been found to be 30-100 times the regulatory level for classifying a waste as hazardous [52]. Lead can find itself into the environment through waste incineration [8] and can contaminate water which eventually gets into the body if drunk. The buildup of lead in the body has a hematologic effect [9], causing various health problems including brain damage, hearing loss and anaemia [14] to name a few. Cadmium, lead, mercury and arsenic have negative effects on children's renal system, with cadmium being released in urine necessitating the need to control all potential sources of contamination [13], including E-waste from computers.

Cadmium which is associated with cancer [45; 36] is also found in computers. Kim Schoppink, a Toxics Campaigner at Greenpeace reports other health consequences of computer waste such as "damage to the nervous system and to brain development" [21]. The presence of such health complications in poorer parts of the world could easily lead to death as most of the medical sectors of these countries lack the expertise and technology to adequately deal with some complications. In fact, there is a great shortage of medical practitioners due to exodus to western countries for greener pastures [7].

With E-waste increasingly becoming a big problem in Africa, the question is whether green IT is a solution and what considerations to adopt green IT in Africa.

4. The solution is green

The greener the vegetation, the better chance of a healthier life for humans and other animals. It is typical in some African villages for farmers to try to get rid of weeds by gathering and burning them in the open air, thus destroying other crops around. A similar habit is practised involving burning unwanted electronic components in fields. Common sense would teach us not to burn our crops either through bushfires or toxic E-wastes, if we would harvest much and reduce malnutrition and disease. The solution therefore is green. To reduce E-waste, green practices need to be adopted.

It is common in most sub-Saharan African countries to have fluctuations in electricity supplies and hence frequent blackouts which further accelerate the “death” of the mainly refurbished computers that are used in various sectors of the society. Entrepreneurs could resort to alternative sources of energy to run computers in such countries which suffer from this problem. Unfortunately, initiatives like the One Laptop Per Child - providing devices that could be powered mechanically with less energy consumption and at very affordable cost - have not been well supported [41]. For green IT to be fully adopted, manufacturers of computers need to work together and to support each other, by adopting green computing policies and becoming key players in fostering such policies by not only trying to implement it themselves in order to have a positive image from the society, but by also supporting other manufacturers with similar interests.

Africa is a place with much sunshine, and hence solar energy could be used as a source of renewable energy to run computers manufactured for African use. This energy could be more abundant, helping to solve the problems of frequent electricity cuts characteristic of many countries in sub-Saharan Africa. These electricity cuts only help to precipitate the failure of the computers, necessitating their disposal. Manufacturers would therefore need to have this source of energy in mind, to meet the needs of their consumers in a greener way and also to promote sustainable computing. Money used in repairing computers that easily break down could be pumped into the economy to boost it and hence to solve some of the many social problems resulting from poverty such as increase in crime rates, juvenile delinquencies, rural exodus, increased emigration, etc.

Given that the quest to bridge the digital divide indirectly compounds the problem of E-waste, it is relevant to examine how the digital divide could be further reduced, bearing in mind the role of green IT.

5. Recommendations for reducing the digital divide and e- waste

In order to bridge the digital divide and to reduce E-waste in Africa, governments, companies and individuals need to work together. By adopting green policies and respecting rules and regulations, with each party committed to promoting greenness, there will be an amelioration of the situation. The following recommendations therefore will help this cause.

5.1 Education and Communication

How we get the message over is an important issue, answering questions such as “What does Green IT mean” and “how can I be green?” Obvious examples are recycling and this is now prescribed in EU law [20]. The

move to electronic documents, email, shared resources, code re-use, virtual servers replacing real hardware ones, green software engineering (should life cycle development models [e.g. 6] have a green risk evaluation at each of its iterations?), what role might Open Source play; are important questions to answer. It is both important to establish a Green curriculum for Green IT and an implementation plan for its recommendation and adoption. We think it important to be Green evangelists, but to do so in the full knowledge of what modern communication and networking makes possible. In order to educate those we wish to influence we have to drive the message home. As many of those who are contributors to E-waste both now and in the future are currently using this very same technology, one way of getting the message home is to look to use Computer Mediated Communication (CMC) as a delivery vehicle. The idea of cultural mediation was introduced in the 1970s, and we can see in the context of shared languages and meaning on the web the importance of social interaction in the days of the social networks [49]. How we architect such scaffolding is beyond the scope of this paper, but is considered elsewhere [eg 46; 40; 18; 16; 25]. The underpinning message here is how we get the message out there that you need to be green and this is how you do it. We need to determine the rules of Green IT and how we teach them effectively and consider how we can use modern communication technology as the way to get these ideas out there. Given that the very people who might contribute to E-waste are those that are on-line, it would seem that we are preaching to the converted if we try to appeal to them to be green. As a consequence of this, can we use the medium of computer mediated communication (CMC) as a medium to disseminate the message of green IT. There is the issue about how we do this. Among failing approaches are the following: Edu-Portals, Laptops for all with no “vision”, web surfing, copy pasting, Learning Objects, CAL/Authoring Environments, IMS, LMS, School software maintenance contract, and edutainment [17]. He laments that after all this time the take up of large scale usage of eLearning systems is limited and the experience frequently poor. We shall return to the future potential of this in the next section. The prospect of debates on Green Issues using CMCs is however a more optimistic one. An early example of using the internet to develop debate on green issues is contained in the British OU Windfarm for the Ambridge project [2]. This was an extension of BBC Radio Radio Soap Opera about the issues of locating a Windfarm on a fictional beauty spot. Initially debated using face-to-face this was migrated onto an early CMC system called COSY and much spirited debate was had. With the advance of Virtual Reality linked to laser scanning it is quickly possible to develop VR applications that can show the transformation of some proposed development. Whilst the green debate is about what to do, often centering on green vs. NIMBY issues, the debate can be widened to more fundamental green issues that are then brought to centre stage. Leading from this discussion we thus feel that it is important that Green Issues enter the Higher Education Curriculum for Computing given their importance given the current zeitgeist. The software discussed in the next section only makes this debate easier to have.

5.2 The potential of Web 2.0

Web 2.0 moves the potential on from what we have seen in the last section. Web 2.0 software is listed to include within the context of the educational domain the following [22]:

- Blogs
- Wikis

- Social Bookmarking
- Media Sharing Services
- Social Networking and Social Presence Systems
- Collaborative editing tools
- Syndication and notification technologies
- Bricolage and Mashup

It is informative to compare this list with Eisenstadt's list of elearning successes, namely:

- Ownership: YouTube, NotSchool, CLUTCH
- Smartboards with vision
- Blogging; MTN; Wikipedia; My Space
- Simulating; solving, goal based learning
- Cognitive Tutor/Environments
- SMS; IM
- Debugging clubs
- BitTorrent; GTA III; Second Life?

Assuming a digital divide can be overcome, we can see the potential for much shared debate. The development of web communities that share an eSociety, a common language [49], a shared and common learning space [50], goals, and values is clearly about us. Virtual online communities abound [e.g. Facebook, eBay, MySpace, Twitter, YouTube]. The use of such vehicles to spread a green message is by the very people who are both of the *hoi polloi* of technology use and the potential E-wasters of them. By pitching to the very people who are the likely cause of the problem we can look to stifle the problem at root. If the users of technology are fully aware of the green consequences of its use then we can look to place the green agenda at the core of IT practicing. A shared taxonomy of use and *folksonomy* of Web 2.0 society and practice which develops the promotion of the green message is essential to achieve Green IT. As Franklin and van Harmelen noted, Web 2.0 isn't going to solve everything by itself. We have looked here at various ways that it could be usefully employed. It has however to be used alongside other methods and agencies which we now go on to consider. Note the use of the above does not imply that we necessarily need new, very modern, machines. Many of these new interaction styles will not generate greater resource requirements, indeed some new message systems [e.g.

TwitterTM] may actually cut down traffic. In the context of Africa there are areas where, even with the expansion of bandwidth seen in recent years, it will still not enable them to use the benefits of Web 2.0. However in other areas and through large parts of the A scan through the references to this paper already show how lobby groups are using this type of technology to get their message home. Such social sharing, communication ability, might provide the right forum to motivate Students/Users on Green Issues.

5.3 Government Organisations

Governments need to encourage projects which seek to develop green sources of energy. Much effort to adopt green strategies is initiated by individuals or non-governmental institutions which do not often receive much support from their governments. By supporting these organisations, the government will help to reduce E-waste. Support from governments will facilitate green IT adoption. This can be done through government policies which will promote green IT. Various governmental departments such as education, environment, development, etc. could help to implement green IT adoption. It is by governments setting the pace that other organisations and individuals will join in and work together to achieve good results. Some local councils in some sub-Saharan African countries do not yet have the facilities and expertise to recycle household waste let alone E-waste. Governments will need to pump in more money into increasing the expertise and capacities of such councils and to encourage E-waste recycling. Local council staff requiring advanced training in waste management could learn from their counterparts in other countries which serve as good examples of E-waste management through internships and then implement them when they return home. Governments through their ministries responsible for primary, secondary and higher education as well as technical and vocational education need to incorporate green IT education into the curriculum and ensure that such subjects have much practical components and hands on approach to delivery, for greater effectiveness. Governments might also promote green IT by reducing tax on green ICTs that are imported or manufactured locally and imposing heavy taxes on those that do not adhere to regulations. Also, enforcement mechanisms need to be put in place to promote government's green ICT policies and strategies.

5.4 Non-Governmental Organisations

International organisations and donor agencies working to bridge the digital gap in Africa need to ensure those recipient organisations in Africa and other developing nations have the capacity to recycle the refurbished computers they ship. If there is no access to such facilities in their vicinity, alternative solutions need to be sought. Additionally, international organisations and aid agencies need to ship recyclable computers and preferably those that adhere to green IT policies. Manufacturers need to place tags on computers that show their degree of greenness following established guidelines such as AAA [100% recyclable], AA [50% recyclable], A [25% recyclable], etc. This will inform decisions on which computers to purchase. As most organisations and individuals receiving computers in developing countries may not be fully aware of the consequences of E-waste or the need for green options, partner organisations abroad need to provide appropriate support on E-waste management through education. Again, manufacturers and suppliers of computers need to work together with local governments and individuals to promote green IT, by adhering to legislation.

5.5 Local Inhabitants

Individuals also have a responsibility in adopting and promoting green IT in order to reduce E-waste. Networks of individuals in communities interested in promoting green IT could be formed to act as a local neighbourhood watchdog to prevent E-waste disposal. This could be done by being involved in green IT education and encouraging others to recycle E-waste. Individuals in their networks need to provide peer-to-peer support and collaboration in green IT adoption. In some sub-Saharan African countries like Cameroon, associations and organisations as well as common initiative groups of people with similar interests are formed, to promote their interests. Such groups with special interest in green IT and E-waste management could be formed to promote green IT and E-waste disposal and hence help reduce the negative consequences of such wastes. It is by working as a network in collaboration with governments and non-governmental organisations that the local inhabitants can succeed in their struggle to bridge the digital divide and also to reduce E-waste disposal through green IT.

6. Conclusion

This paper has been about how we deliver Green IT within the emerging Knowledge Society with a particular reference to E-waste in Africa. We established that E-waste results from buying used computers to bridge the digital divide, even when these computers easily breakdown and need to be discarded, necessitating education to solve the problem. We have emphasized the role of education and new Web 2.0 communication Mashups have to play in this process and how the Knowledge Society can change both our definitions and employment of both of these concepts. This however is not enough and can only be part of the story with individuals, organizations, and indeed governments very much part of the movement. It is not always easy to be green, we need to motivate and empower IT users to be green, motivate them to adopt this lifestyle, educate them both to the agenda, consequences, repercussions and practical lifestyle choices and actions that ensue. A positive choice of a green outlook can make a major change to how we use and consume technology and provide a powerful antidote to E-waste problems. The consequences of not bringing this to the forefront of computer pedagogy are considerable.

7. General recommendations

By working to create a cleaner environment through community service efforts, the application of earth-friendly technology and practices, research projects, and responsible development planning, we will strive to work for a better tomorrow. Through education and community outreach, we will provide our citizens with the knowledge and skills to be environmentally responsible citizens and consider the global ramifications of their actions and the actions of others around them. To this end, the following recommendations will greatly boost continuous improvement in:

- *Incorporation of environmentally responsible concerns in stakeholders decision making.*
- *Demonstration of institutional practices that promote sustainability, including energy savings measures, increasing the use of renewable resources, and decreasing production of waste materials.*

- *Providing educational programs and encouraging environmental inquiry for students and the community concerning positive environmental practices.*
- *Establishment of sustainability indicators to enable monitoring, reporting and improvement measures.*
- *Enhancing the health of national ecosystems and increasing the diversity of native species whenever possible.*
- *Promotion of health, productivity and safety practices through education, maintenance and design of infrastructures.*
- *Create a recycling/sustainability position especially in Ministries incharge of Technology.*
- *Continue to support the current energy management and conservation initiatives.*
- *Increase communication efforts - develop a public sustainability website*
- *Make a public commitment to environmental sustainability*
- *Promote the infusion of sustainability principles*

The nations in Africa should promote the infusion of sustainability principles into appropriate areas of the curriculum while encouraging and coordinating co-curricular activity in the area of sustainability. Policy and information support for Green Technology initiative will be needed for this to occur. It is my believe that if these recommendations, implemented individually or collectively, will be important initial steps toward sensitizing stakeholders to the issue of environmental sustainability and to encouraging a lifelong commitment to this important issue. These basic initiatives are in line with actions taken by many of our benchmark institutions, and will provide the framework from which to move Green Technology toward becoming a fully sustainable initiative.

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References

- [1] Anderson, W. "Welcome to Lagos-it'll defy your expectations." [Online] British Broadcasting Corporation. Available: <http://www.bbc.co.uk/blogs/tv/2010/04/welcome-to-lagos-itll-defy-you.shtml> [Accessed: 22 July, 2010].
- [2] Basel Convention, "The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal". Available <http://www.basel.int/>[Accessed: 21 March, 2010]
- [3] BBC, "Computer ownership on the rise". [Online]British Broadcasting Corporation. Available: <http://news.bbc.co.uk/1/hi/uk/3523350.stm> [Accessed: 21 July 2010].
- [4] BBC, "Ghana's growing E-waste trade". [Online] British Broadcasting Corporation. Available: <http://news.bbc.co.uk/1/hi/world/africa/7544003.stm> [Accessed: 22 March 2010].
- [5] Berners-Lee, T, Hendler, J. and Lassila, O., The Semantic Web, Scientific America.[2002]
- [6] Boehm B, "A Spiral Model of Software Development and Enhancement", ACM SIGSOFT Software Engineering Notes", "ACM", 11[4]:14-24. 1986.

- [7] Bourgain, A., Pieretti, P., and Zou, B., "Substitution Policy". CREA Discussion Paper Series 08-13, Center for Research in Economic Analysis, University of Luxembourg, 2008.
- [8] Bull, S., Lead: General Information. [Online] Health Protection Agency. Available: http://www.hpa.org.uk/web/HPAwebFile/HPAweb_C/1194947322388 [Accessed: 14 October 2010].
- [9] Clarkson, T.W., Weiss, B., and Cox, C., Public Health Consequences of Heavy Metals in Dump Sites. *Environ Health Perspective*. Feb.1983: pp.113-27.
- [10] Cobbing, M. [2008]. Toxic Tech: Not in Our Backyard. [Online] Greenpeace International. Available: <http://www.greenpeace.org/international/Global/international/planet-2/report/2008/2/not-in-our-backyard.pdf> [Accessed: 13 October 2010].
- [11] Computer Aid International., Annual Report: 2008/2009. [Online] Computer Aid International. Available:<http://www.computeraid.org/uploads/5112-COMPUTER-AID-INT-Annual-Report.pdf> [Accessed: 20 March 2010].
- [12] Crop Residues Burning Regulations SI 1366/93
http://www.opsi.gov.uk/SI/si1993/Uksi_19931366_en_3.htm
- [13] De Burbure, C. et al., Renal and Neurologic Effects of Cadmium, Lead, Mercury, and Arsenic in Children: Evidence of Early Effects and Multiple Interactions at the Environmental Exposure Levels. *Environmental Health Perspectives*. Pp.114[4]:pp.584-590. 2006.
- [14] Duncan, K.J., Lopez, L., Paharsingh, T., Burnette, E. , The hematologic effects of lead on the peripheral blood of young children. *Journal of Continuing Education Topics & Issues*, April 2007.
- [15] Eisenstadt, M and Brayshaw M, An Integrated Textbook, Video and Software Environment for Novice and Expert Prolog Programmers, In: E.Soloway and J.Spohrer [Eds.], *Understanding the Novice Programmer*, Hillsdale, NJ: Lawrence Erlbaum Associates, 1987.
- [16] Eisenstadt, M., and Brayshaw, M., A fine-grained account of Prolog execution for teaching and debugging, *Instructional Science*, 1990.
- [17] Eisenstadt, M., Does E-Learning Have to be this Awful? [Time to Mashup or Shutup], Keynote address, IEEE 7th International Conference on Advanced Learning Technology, Niigata, Japan, 18-20 July, pp 6-10. 2007.
- [18] Elsom-Cook,, Design Consideration for an intelligent tutoring system for LISP [unpublished PhD Thesis], Department of Psychology, University of Warwick. 1984.
- [19] Elsom-Cook, M., Guided Discovery Tutoring in M Elsom-Cook [Ed] *Guided Discovery Tutoring: A Framework for ICAI Research*, London: Paul Chapman, ISBN 0442308353. 1990.
- [20] EU., Directive 2002/96/EC of the European Parliament and of the Council of 27 January 2003 on waste electrical and electronic equipment [WEEE]. 2003.
- [21] Ford, M., Sifting through the mounting problem of E-waste. [Online] CNN. Available: <http://www.cnn.com/2009/TECH/science/08/02/E-waste.recycling/index.html> [Accessed: 20 March 2010].
- [22] Franklin, T, and van Harmelen, M, Web 2.0 for Content Learning and Teaching in Higher Education, Report prepared for JISC, May 2007 [online] Available: <http://www.jisc.ac.uk/media/documents/programmes/digitalrepositories/web2-content-learning-and-teaching.pdf> [Accessed: 21st July, 2018].

- [23] Fuchs, C. and Horak, E., "Africa and The Digital Divide". *Telematics and Informatics* **25**: pp. 99-116. 2008.
- [24] Furuholt, B., and Kristiansen, S., "A rural-urban digital divide? Regional aspects of internet use in Tanzania". Proceedings of the 9th International Conference on Social Implications of Computers in Developing Countries, Sao Paulo, Brazil, May 2007.
- [25] Gordon, N and Brayshaw, M., Inquiry based Learning in Computer Science Teaching in Higher Education [Online] Available: <http://www.ics.heacademy.ac.uk/italics/vol7iss1/pdf/Paper2.pdf> [Accessed 15/11/2008].
- [26] ITU., Telecommunication/ICT Markets and Trends in Africa. [Online] International Telecommunication Union. Available: http://www.itu.int/ITU-D/ict/statistics/material/af_report07.pdf [Accessed: 14 October 2010].
- [27] ITU., African Telecommunication/ICT Indicators 2008. International Telecommunication Union, Geneva- Switzerland. [Online]
- [28] ITU., The World in 2009: ICT Facts and Figures. [Online] International Telecommunications Union. Available: <http://www.itu.int/net/pressoffice/backgrounders/general/pdf/3.pdf> [Accessed: 14 October 2010].
- [29] ITU., World Telecommunication/ICT Development Report 2010: Monitoring the WSIS Targets- A mid- term review. International Telecommunication Union, Geneva Switzerland, 217pp. 2010.
- [30] Kahhat, R., Williams, E., Product or waste? Importation and end-of-life processing of computers in Peru. *Environ Sci Technol.* 43 [25]: pp. 6010-6016. 2009.
- [31] Kiran, Y. and Sahin, A., The Effects of Cadmium in Seed Germination, Root Development and Mitotic Of Root Tip Cells of Lentil [*Lens culinaris Medik.*]. *World Journal of Agricultural Sciences* 2[2]: 196-200, 2006.
- [32] Kelly, T., Twenty Years of Measuring the Missing Link. In *The Economist*, October 2005. London: The Economist. [Online] Available: <http://www.itu.int/osg/spu/sfo/missinglink/kelly-20-years.pdf> [Accessed: 14 October 2010].
- [33] LaDou, J., Lovegrove, S., Export of electronic equipments waste. *Int J Occup Environ Health.* **14** [1]: pp. 1-10. 2008.
- [34] Lee, C.H., Chang, S.L., Wang, K.M., Wen, L.C., Management of scrap computer recycling in Taiwan. *Journal of Hazardous Materials.* 73 [3]: 209-220. 2000.
- [35] London Evening Standard, The future is flat as Dixon's withdraws sale of „Big Box“ televisions, [Online] Available: <http://www.thisislondon.co.uk/news/article-23376023-the-future-is-flat-as-dixons-withdraws-sale-of-big-box-televitions.do> [Accessed: 21 July 2010].
- [36] Nawrot, T. et al., Environmental exposure to cadmium and risk of cancer: a prospective population-based study. *The Lancet Oncology*, Vol. 7, Issue 2, pp.119-126. 2006.
- [37] Nganji, J.T., ICTs and Disability- Towards an Inclusive Implementation in Africa. Proceedings of the International Conference on ICT for Africa, Yaounde, Cameroon, December 2008.
- [38] Nganji, J., Kwemain, R. and Taku, C., Closing the digital gap in Cameroonian secondary schools with the CIAC project. *International Journal of Education and Development Using ICT*, Volume 6, Issue 2. 2010.

- [39] Nnorom, I.C., Osibanjo, O., Electronic waste [E-waste]: material flows and management practices in Nigeria. *Waste Management*. 28 [8]: 1472-9. 2008.
- [40] O'Shea T and Self J., *Learning And Teaching With Computers: Artificial Intelligence in Education*, Great Britain: The Harvester Press Limited. 1983.
- [41] Pell, A., The £50 laptop to change the world. [Online] *The Sunday Times*. Available: http://technology.timesonline.co.uk/tol/news/tech_and_web/personal_tech/article1394717.ece [Accessed: 20 March 2010].
- [42] Prashant, N., Green Technology: Cash for Laptops offers "Green" for broken or outdated computers, TMCnet [online] Available: <http://green.tmcnet.com/topics/green/articles/37567-cash-laptops-offers-green-solution-broken-outdated-computers.htm> [Accessed 21st July, 2010].
- [43] Puckett, J, Byster, L, Westervelt, S, Gutierrez, R, Davis, S, Hussain, A., and Dutta, M., *Exporting Harm: The High Tech trashing of Asia*, Report for the Basel Action Network [online], Available: <http://www.ban.org/E-waste/technotrashfinalcomp.pdf> [Accessed 21st July, 2010].
- [44] Schmidt, C.W., Unfair Trade E-waste in Africa. *Environmental Health Perspectives*, 114 [4]: 232-235.
- [45] Schwartz, G.G. and Reis, M., Is Cadmium a Cause of Human Pancreatic Cancer? *Cancer Epidemiology, Biomarkers & Prevention*, Vol. 9, 139-145, February 2000.
- [46] Sleeman, D., and Brown, J.S., *Intelligent Tutoring Systems*, Academic Press [London], 1983, ISBN 0-12-648680-8.1983.
- [47] Sohrabji, S., India's Poor Recycle World's E-waste into Wealth. [Online] http://news.ncmonline.com/news/view_article.html?article_id=c2df984bffe1d99715ed96496e015ce5 [Accessed: 22 March 2010].
- [48] Vicente, M.R. and Lopez, A.J., A Multidimensional Analysis of the Disability Digital Divide: Some Evidence for Internet use. *The Information Society An International Journal*, **26**[1]1, 2010.
- [49] Vygotsky, *Interaction between learning and development*, In *Mind and Society*, Cambridge, Mass: The Harvard University Press, pp79-91. 1978.
- [50] Wheeler, S., Learning Space Mashups: Combining Web 2.0 Tools to Create Collaborative and Reflective Learning, *Future Internet* **1**, 3-13. 2009.
- [51] Wong, M., Flat Panels drive old TVs from market, *USA Today*. [Online] Available: http://www.usatoday.com/tech/products/gear/2006-10-22-crt-demise_x.htm [Accessed: 20 July 2010].
- [52] Yadong Li, Richardson, J.B., Walker, A.K., Yuan, P.C., TCLP heavy metal leaching of personal computer components. *Journal of environmental engineering*. Vol. 132, no4, pp. 497-504. 2006.