Journal of Education and Practice www.iiste.org
ISSN 2222-1735 (Paper) ISSN 2222-288X (Online)
Vol 2, No 3

E-waste Management: Teaching how to Reduce, Reuse and Recycle For Sustainable Development- Need of Some Educational strategies

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Abstract

The constantly changing world of technology is the world's largest and fastest growing manufacturing industry. The vast growth and rapid product obsolescence has brought about the serious problem of e-waste, which is now the fastest growing form of waste in the industrialized world. E-waste encompasses a broad and growing category of electronic devices ranging from large household appliances such as refrigerators, microwave ovens and air conditioners to consumer electronics such as cellular phones, televisions, personal stereos and computers. Electronic equipment contains a variety of toxic ingredients, including hazardous heavy metals that pollute the environment and are very dangerous to human health. This paper discusses some of the principles that are being employed to alleviate the environmental impact of e-waste such as extended producer responsibility, design for environment (DfE), consumer driven solutions. This article also discusses educational strategies that can be employed to educate global audiences; this paper highlights the hazards of e-wastes, the need for its appropriate management and options that can be implemented.

Keywords: electronic waste; e-waste; e-waste education; sustainable development; e-waste strategy.

1 Introduction

"E-waste" is a popular, informal name for electronic products nearing the end of their "useful life."E-wastes are considered dangerous, as certain components of some electronic products contain materials that are hazardous, depending on their condition and density. The hazardous content of these materials pose a threat to human health and environment. Discarded computers, televisions, VCRs, stereos, copiers, fax machines, electric lamps, cell phones, audio equipment and batteries if improperly disposed can leach lead and other substances into soil and groundwater. Many of these products can be reused, refurbished, or recycled in an environmentally sound manner so that they are less harmful to the ecosystem.

The manufacturing of electrical and electronic equipment (EEE) is one of the fastest growing global industries. This rapid expansion is resulting in an increase of waste electric and electronic equipment (WEEE) which is also referred to as electronic waste (e-waste). The average lifespan of electric and electronic equipment is becoming shorter, while the amount of related waste is increasing (Karagiannidis et al., 2005; Feszty et al., 2003). E-waste has become one of the fastest growing areas of the international waste stream and is increasing at a much higher rate than all other such streams (Herat, 2007). The information communication technology (ICT) revolution, global economic progress, coupled with urbanization and insidious appetite for consumer electronics such as personal computers (PC), cell phones and home electronics has increased both the consumption of EEE and the production e-waste. The main problem with e-waste generated from PCs is the fact that computers are manufactured from over 1,000 different materials (Herat, 2007). Some of these materials are toxic and not only cause environmental pollution but have been linked to human health problems (Chan et al., 2007). There are new practices being adopted globally that will lead to the sustainable management of e-waste such as: design for environment (Herrmann et al., 2002), innovative product design (Arnold, 2004), extended producer responsibility (Hume et al., 2002), standards and labeling, and recycling and remanufacturing (Fickes, 2004).

However one of the most important practices to effectively deal with the e-waste stream is to educate people (Babu et al., 2007).

To tackle the future environmental problems that will eventually occur from improper management of e-waste, many developed countries and organizations have drafted legislation to address the reuse and recycling material recovered from EEE to reduce the amount of toxic materials disposed in landfills. Recycling of e-waste is important, because it allows the recovery of valuable material and reduces the amount of waste requiring disposal. One factor that should be considered with e-waste is the potential loss of resource from electrical and e-waste (King et al., 2006) in Europe alone an estimated 2.4 million tons of ferrous metals, 1.2 million tons of plastics and 0.65 million tons of copper was considered lost over a decade ago, this figure will have increased drastically based on the growth in consumer electronic over the last decade (AEA Technology, 1997).

There are numerous initiatives underway in the USA and European Union (EU) to tackle the growing e-waste problem (Huisman and Magalini, 2007). However, e-waste is not a problem unique to developed nations (Huisman and Magalini, 2007). It is now undeniable that developing countries own a substantial share of EEE. It is estimated by Greenpeace that out of an estimated 20–50 million tons of e-waste discarded globally each year, Asian countries are responsible for an estimated 12 million tons. This figure is likely to increase substantially over the next decade due to the economic growth of China and India, who will have 178 million and 80 million new computers, respectively, out of the global total of an estimated 716 million new computer users by 2010 (Greenpeace, 2008).

Another EEE device that is experiencing an increase adoption in developing countries is the cell phone. Molly Sheeham (2003) highlights the fact that Uganda became the first African nation to have more mobile than fixed-line customers in 1999; a decade later reveals that over 30 other African nations have followed this trend. The task of creating a sustainable future must be shared between both developing and developed nations. Currently the main discussion points in the media surrounding e-waste and role of developing nation is focused on fact that e-waste is often sent for recycling and refurbishing in developing countries (Osibanjo and Nnorom, 2007) due to the cheap labour, it is estimated that 50–80% of the e-waste collected for recycling in the US is exported to countries such as China, India, Nigeria and Pakistan. There is no denying the problems created by exporting e-waste, but to truly address this problem both developing and developed countries must implement comprehensive education strategies that allow local population to understand the impact of e-waste on environmental population from their unique point of view. It is important to consider all countries as equal participants in the problem as well as the solution. The aim of this paper is to provide an overview of the various practices that are evolving around the world to tackle the e-waste problem and to discuss educational strategies that can be implemented at various levels in society to enlighten people on the problems of e-waste. The paper is structured as follows: The first section provides an overview of what constitutes e-waste and discusses the health implications. This is followed by a discussion on some of the innovative concepts that are being implemented to tackle the problem such as designing for the environment, consumer awareness, along with innovative product design. Prior to the conclusion, a discussion on educational strategies is provided such as whole systems design, sustainable engineering, green IT and multi discipline e-waste introductory courses.

2 E-waste overview

industrial revolution followed by the advances in information technology during the last century has radically changed people's lifestyle. Although this development has helped the human race, mismanagement has led to new problems of contamination and pollution. The technical prowess acquired during the last century has posed a new challenge in the management of wastes. For example, personal computers (PCs) contain certain components, which are highly toxic, such as chlorinated and brominated substances, toxic gases, toxic metals, biologically active materials, acids, plastics and plastic additives. The hazardous content of these materials pose an environmental and health threat. Thus proper management is necessary while disposing or recycling ewastes.

These days computer has become most common and widely used gadget in all kinds of activities ranging from schools, residences, offices to manufacturing industries. E-toxic components in computers could be summarized as circuit boards containing heavy metals like lead & cadmium; batteries containing cadmium; cathode ray tubes with lead oxide & barium; brominated flameretardants used on printed circuit boards, cables and plastic casing; poly vinyl chloride (PVC) coated copper cables and plastic computer casings that release highly toxic dioxins & furans when burnt to recover valuable metals; mercury switches; mercury in flat screens; poly chlorinated biphenyl's (PCB's) present in older capacitors; transformers; etc. Basel Action Network (BAN) estimates that the 500 million computers in the world contain 2.87 billion kgs of plastics, 716.7 million kgs of lead and 286,700 kgs of mercury. The average 14-inch monitor uses a tube that contains an estimated 2.5 to 4 kgs of lead. The lead can seep into the ground water from landfills thereby contaminating it. If the tube is crushed and burned, it emits toxic fumes into the air.

The vast growth in EEE and rapid product obsolescence has brought about the serious problem of e-waste, which is now the fastest growing form of waste in the industrialized world (Grossman, 2006). There is no generally accepted definition of e-waste and there is not a consistent list of which electronic products constitute e-waste. Previous research on e-waste has focused on items such as cell phones, computers, monitors and consumer electronics (McCullar et al., 2004), while other researchers such as Puckett et al. (2002) and Basel Action Network (BAN) also include large household equipment as e-waste. A general definition of e-waste is 'e-waste encompasses a broad and growing range of electronic devices ranging from large household appliances such as refrigerators, air conditioners, mobile phones, personal stereos and consumer electronics to computers' [Puckett et al., (2002) p.5] The most specific definition was proposed by the EU, 'equipment which is dependent on electric currents or electromagnetic fields in order to work properly and equipment for the generation, transfer and measurement of such currents and fields... and designed for use with a voltage rating not exceeding 1 000 Volt for alternating current and 1 500 Volt for direct current' (European Union, 2003).

Many developing countries have taken on the business of 'recycling' e-waste imported from developed countries such as Canada and the USA. Workers strip off re-usable components and incinerate what's left over. The result is a metal stream that is sold at a price based on the composition of the metals. The cost of this process is much less in developing countries because the laws to regulate recycling are more lax if they exist at all. The process of disassembling, smelting, cooling and recycling electronics is done carelessly and in an environmentally unfriendly manner (Dillon, 1999). This low cost to export e-waste is very appealing to countries such as the USA and Canada. Exporting allows developed countries to keep their landfills toxic-waste free which enables countries to meet the national standards of 'recycling e-waste' at a considerably lower cost than if it were done locally (Repa, 2005). It seems clear that developing components that are environmentally friendly is not only the ethical position to take in addressing the problem of e-waste but also, in the long run, the most cost effective. Companies would benefit from government grants for research and development along with tax break incentives for developing new environmentally friendly components, this would help companies realize monetary gains from moving forward in this direction (Jacobsohn, 2003).

The sacrifices being made from the disposal and recycling of e-waste are high. Many articles, blogs and environmentalists websites report on recycling centers located mostly in underdeveloped Asian countries; describe thousands of children, unmasked and unprotected, dipping components in acid baths to remove the metals or incinerating toxic materials, breathing the fumes without any form of protection. Populations of people are living among thousands of piles of electronic scrap that when broken are emitting toxic fumes (Miller, 2005). Not only are these dump sites seriously polluting the environment but they are causing alarming increased rates of cancer, retardation and neurological disorders. It seems that governments are willing to sacrifice the health and safety of the environment and foreign citizens for the sake of convenient, cost effective disposal of 'obsolete' technology in favor of the latest innovation (O'Connell, 2007). In developing countries, when these materials are discarded into landfills the acidic conditions cause these harmful materials to leak out pass through the liners of the landfills going right into groundwater. These materials can also harm the environment by damaging the air and the soil. Dangerous materials such as Lead, cadmium and mercury are all found within e-waste. Lead is found in the glass of computer monitors and in printed circuit boards. If exposed to lead this could lead to damage to the central nervous system and kidneys. In addition effects on the endocrine system have been observed, leading to serious negative effects on children's brain development.

Cadmium is found in the older models of cathode ray tubes (glass panels in computer monitors) and also in plastics. Cadmium is classified as toxic, if exposed to the human body it poses an irreversible risk to health causing kidney failure. In addition, mercury, found in thermostats, position censors, relays, switches, discharge lamps, batteries and printed wiring boards has shown to invade living organisms and travel through the human body causing negative effects on the brain. Hexavalent chromium, is found in untreated steel plates can cause strong allergic reactions to the human body. PVC is found in the cabling and computer housings and when introduce to intense heat or fire generate dioxins and furans can contribute to air pollution and respiratory ailments. Brominated flame retardants are found in printed circuit boards and plastics that cover TV and computers. If exposed to these toxic chemicals, it can cause harmful effects to the neurological system along with a higher risk of getting cancer of the lymph nodes.

Effects on environment and human health-

Disposal of e-wastes is a particular problem faced in many regions across the globe. Computer wastes that are land filled produces contaminated leachates which eventually pollute the groundwater. Acids and sludge obtained from melting computer chips, if disposed on the ground causes acidification of soil. For example, Guiyu, Hong Kong a thriving area of illegal e-waste recycling is facing acute water shortages due to the contamination of water resources.

This is due to disposal of recycling wastes such as acids, sludges etc. in rivers. Now water is being transported from faraway towns to cater to the demands of the population. Incineration of e-wastes can emit toxic fumes and gases, thereby polluting the surrounding air. Improperly monitored landfills can cause environmental hazards. Mercury will leach when certain electronic devices, such as circuit breakers are destroyed. The same is true for polychlorinated biphenyls (PCBs) from condensers. When brominated flame retardant plastic or cadmium containing plastics are landfilled, both polybrominated dlphenyl ethers (PBDE) and cadmium may leach into the soil and groundwater. It has been found that significant amounts of lead ion are dissolved from broken lead containing glass, such as the cone glass of cathode ray tubes, gets mixed with acid waters and are a common occurrence in landfills.

Not only does the leaching of mercury poses specific problems, the vaporization of metallic mercury and dim ethylene mercury, both part of Waste Electrical and Electronic Equipment (WEEE) is also of concern. In addition, uncontrolled fires may arise at landfills and this could be a frequent occurrence in many countries. When exposed to fire, metals and other chemical substances, such as the extremely toxic dioxins and furans (TCDD tetrachloride dibenzo-dioxin, PCDDs-polychlorinated dibenzodioxins. PBDDs-polybrominated dibenzo-dioxin and PCDFspoly chlorinated dibenzo furans) from halogenated flame retardant products and PCB containing condensers can be emitted. The most dangerous form of burning e-waste is the open-air burning of plastics in order to recover copper and other metals. The toxic fall-out from open air burning affects both the local environment and broader global air currents, depositing highly toxic byproducts in many places throughout the world.

Table I summarizes the health effects of certain constituents in e-wastes. If these electronic items are discarded with other household garbage, the toxics pose a threat to both health and vital components of the ecosystem. In view of the ill-effects of hazardous wastes to both environment and health, several countries exhorted the need for a global agreement to address the problems and challenges posed by hazardous waste. Also, in the late 1980s, a tightening of environmental regulations in industrialized countries led to a dramatic rise in the cost of hazardous waste disposal. Searching for cheaper ways to get rid of the wastes, "toxic traders" began shipping hazardous waste to developing countries. International outrage following these irresponsible activities led to the drafting and adoption of strategic plans and regulations at the Basel Convention. The Convention secretariat, in Geneva, Switzerland, facilitates and implementation of the Convention and related agreements. It also provides assistance and guidelines on legal and technical issues, gathers statistical data, and conducts training on the proper management of hazardous waste.

3 Tackling the e-waste problem

The e-waste strategy illustrated in Figure 1 was adapted from the 2000 for England and Wales waste strategy DEFRA (2007). The four levels presented are in order of preference to ensure environmental sustainability (Defra 2007):

Level 1 Waste reduction (such as extending product durability)

Level 2 Waste re-use (such as remanufacturing products for a second life)

Level 3 Waste recovery (such as raw material recycling)

Level 4 Waste landfill (as the last resort).

A set. Of interrelated and mutually supportive strategies are proposed to support the concrete implementation of the activities as indicated in the website (www.basel.int/DraftstrateKJcpian4Seot.pdf) is described below:

- To involve experts in designing communication tools for creating awareness at the highest level to promote the aims of the Basel Declaration on environmentally sound management and the ratification and implementation of the Basel Convention, its amendments and protocol with the emphasis on the short-term activities.
- To engage and stimulate a group of interested parties to assist the secretariat in exploring fund raising strategies including the preparation of projects and in making full use of expertise in non-governmental organizations and other institutions in joint projects.
- To motivate selective partners among various stakeholders to bring added value to making progress in the short-term.
- To disseminate and make information easily accessible through the internet and other electronic and printed materials on the transfer of know-how, in particular through Basel Convention Regional Centers (BCRCs).
- To undertake periodic review of activities in relation to the agreed indicators;
- To collaborate with existing institutions and programmes to promote better use of cleaner technology and its transfer, methodology, economic instruments or policy to facilitate or support capacity-building for the environmentally sound management of hazardous and other wastes.

4. Management of E-Waste

It is estimated that 75% of electronic items are stored due to uncertainty of how to manage it. These electronic junks lie unattended in houses, offices, warehouses etc. and normally mixed with household wastes, which are finally disposed off at landfills. This necessitates implementable management measures.

In industries management of e-waste should begin at the point of generation. This can be done by waste minimization techniques and by sustainable product design. Waste minimization in industries involves adopting:

- inventory management,
- production-process modification,
- volume reduction,
- Recovery and reuse.

5. The Indian scenario-

While the world is marveling at the technological revolution, countries like India are facing an imminent danger. E-waste of developed countries, such as the US, disposes their wastes to India and other Asian countries. A recent investigation revealed that much of the electronics turned over for recycling in the United States ends up in Asia, where they are either disposed of or recycled with little or no regard for environmental or worker health and safety. Major reasons for exports are cheap labor and lack of environmental and occupational standards in Asia and in this way the toxic effluent of the developed nations 'would flood towards the world's poorest nations. The magnitude of these problems is yet to be documented. However, groups like Toxic Links India are already working on collating data that could be a step towards controlling this hazardous trade. It is imperative that developing countries and India in particular wake up to the monopoly of the developed countries and set up appropriate management measures to prevent the hazards and mishaps due to mismanagement of e-wastes.

6. Management option-

Considering the severity of the problem, it is imperative that certain management options be adopted to handle the bulk e-wastes. Following are some of the management options suggested for the government, industries and the public.

6.1. Responsibilities of the Government

(I) Governments should set up regulatory agencies in each district, which are vested with the responsibility of co-coordinating and consolidating the regulatory functions of the various government authorities regarding hazardous substances.

(ii) Governments should be responsible for providing an adequate system of laws, controls and administrative procedures for hazardous waste management (Third World Network. 1991). Existing laws concerning e-waste disposal be reviewed and revamped. A comprehensive law that provides e-waste regulation and management and proper disposal of hazardous wastes is required. Such a law should empower the agency to control, supervise and regulate the relevant activities of government departments.

Under this law, the agency concerned should -

- Collect basic information on the materials from manufacturers, processors and importers and to maintain an inventory of these materials. The information should include toxicity and potential harmful effects.
- Identify potentially harmful substances and require the industry to test them for adverse health and environmental effects.
- Control risks from manufacture, processing, distribution, use and disposal of electronic wastes.
- Encourage beneficial reuse of "e-waste" and encouraging business activities that use waste". Set up programs so as to promote recycling among citizens and businesses.

Educate e-waste generators on reuse/recycling options -

(iii) Governments must encourage research into the development and standard of hazardous waste management, environmental monitoring and the regulation of hazardous waste-disposal.

(iv) Governments should enforce strict regulations against dumping e-waste in the country by outsiders. Where the laws are flouted, stringent penalties must be imposed. In particular, custodial sentences should be preferred to paltry fines, which these outsiders / foreign nationals can pay.

(v) Governments should enforce strict regulations and heavy fines levied on industries, which do not practice waste prevention and recovery in the production facilities.

(vi) Polluter pays principle and extended producer responsibility should be adopted.

(vii) Governments should encourage and support NGOs and other organizations to involve actively in solving the nation's e-waste problems.

(viii) Uncontrolled dumping is an unsatisfactory method for disposal of hazardous waste and should be phased out.

(viii) Governments should explore opportunities to partner with manufacturers and retailers to provide recycling services.

6.2. Responsibility and Role of industries

Generators of wastes should take responsibility to determine the output characteristics of wastes and if hazardous, should provide management options.

All personnel involved in handling e-waste in industries including those at the policy, management, control and operational levels, should be properly qualified and trained. Companies can adopt their own policies while handling e-wastes.

- Companies can and should adopt waste minimization techniques, which will make a significant reduction in the quantity of e-waste generated and thereby lessening the impact on the environment. It is a "reverse production" system that designs infrastructure to recover and reuse every material contained within e-wastes metals such as lead, copper, aluminum and gold, and various plastics, glass and wire. Such a "closed loop" manufacturing and recovery system offers a win-win situation for everyone, less of the Earth will be mined for raw materials, and groundwater will be protected, researchers explain.
- Manufacturers, distributors, and retailers should undertake the responsibility of recycling/disposal of their own products.
- Manufacturers of computer monitors, television sets and other electronic devices containing hazardous materials must be responsible for educating consumers and the general public regarding the potential threat to public health and the environment posed by their products. At minimum, all computer monitors,

television sets and other electronic devices containing hazardous materials must be clearly labeled to identify environmental hazards and proper materials management.

6.3. Responsibilities of the Citizen

Waste prevention is perhaps more preferred to any other waste management option including recycling. Donating electronics for reuse extends the lives of valuable products and keeps them out of the waste management system for a longer time. But care should be taken while donating such items i.e. the items should be in working condition. E-wastes should never be disposed with garbage and other household wastes. This should be segregated at the site and sold or donated to various organizations.

7. Sustainable product design

Minimization of hazardous wastes should be at product design stage itself keeping in mind the following factors*

- ***Rethink the product design:*** Efforts should be made to design a product with fewer amounts of hazardous materials. For example, the efforts to reduce material use are reflected in some new computer designs that are flatter, lighter and more integrated. Other companies propose centralized networks similar to the telephone system.
- ***Use of renewable materials and energy:*** Bio-based plastics are plastics made with plant-based chemicals or plant-produced polymers rather than from petrochemicals. Bio-based toners, glues and inks are used more frequently. Solar computers also exist but they are currently very expensive.
- ***Use of non-renewable materials that are safer:*** Because many of the materials used are non-renewable, designers could ensure the product is built for re-use, repair and/or upgradeability. Some computer manufacturers such as Dell and Gateway lease out their products thereby ensuring they get them back to further upgrade and lease out again.

8. Extended producer responsibility

Extended producer responsibility (EPR) is seen as the rational expansion of the polluter pays principle. This stems from the argument that the potential impact on the environmental and society are actually determined at the design phase; where key technology and material choices are made (Gertsakis et al., 2000). EPR is defined as the principle that manufacturer and importers of products should bear a significant degree of responsibility for the environmental impacts of their products throughout the product life-cycle, including impacts from the selection of materials, the production process and from the use and disposal of the products at the end of life-cycle' (OECD, 2001). This principle is likely to be implemented to satisfy the WEEE directive on waste EEE. Since August 2004, all EU OEMs (original equipment manufacturers) along with any company that imports into the EU are legally bound to take significant responsibility for the treatment and disposal of post-consumer products (EU, 2003).

9. Consumer driven solutions

If consumers are properly educated to be aware of the consequences of e-waste, they are likely to not only participate in appropriate initiatives but also spread the word about the dangers of e-waste while promoting alternatives solutions to their disposal. An example of a consumer driven solution is concept of free cycle. Free cycle is a US based initiative that works via the use of internet based technologies. Members use features of Yahoo groups such as blogs, e-mails and distribution lists to post details of unwanted items, and other members can act in response to the offers. The company suggests that a conservative estimate of one pound per item exchanged through the group, thereby saving 40 tons per day from landfills (Angel, 2005). Another aspect to the consumer driven approach is 'responsible purchasing'. This stems from the notion that if consumers are aware of the environmental impact of their purchases, they will be inclined to choose between manufactures for the most environmentally friendly products.

10. Innovative EEE designs

In the future engineers and designers of EEE will have to consider e-waste when developing new products, creating mechanical and electrical design interfaces will become more challenging considering regulations from the EU legislation on WEEE and Restriction on Hazardous Materials (ROHS) directives. The fundamental engineering challenge will need to addresses three important themes (Arnold, 2004): The systematically design new electronic products with a high degree of certainty that they will function properly; new product designs must be compliant with new EU directives involving environmental protection and recycling; and all designs must meet stringent US and international electromagnetic compliance requirements.

11. Recycling

Recycling is a series of activities by which discarded materials are collected, sorted, processed, and used in the production of new products (NRC, 1999).

12. Public awareness campaign

Public awareness of the e-waste problem is only a start; the public has to be willing to support the companies that help to properly dispose of the e-waste even if the cost of their products is slightly higher. Consumers hold the power but need to be educated with the facts. The fact is recycling starts with the individual. With a little effort and an internet connection the average individual could learn where to recycle their electronic products.

13. Design for the environment (DfE)

An important concept that has the potential to tackle the e-waste predicament is the Design for Environment (DfE) concept (Mead et al., 1999). The Design for the Environment (DfE) Program is a global initiative that is overseen by either government or nonprofit organizations within a country. DfE organizations typically work in partnership with a variety of stakeholders to reduce risk to people and the environment by preventing pollution. The remit of a DfE program can be broad covering chemical risk reduction, energy efficiency to facilitate positive and sustainable changes chemical assessment tools and expertise to inform companies of substitutions to safer chemistries.

14. Strategies for educating consumers on e-waste

To educate the consumer sector on global e-waste, countries need to take an integrated approach that is unlike the traditional straight-line educating techniques in use today. Educational messaging needs to be supported by multiple channels and needs to come at various stages over time to address various diverse audiences. The straight-line process focuses on each educational step in sequence and traditionally is not flexible enough to address situations at different stages (e.g., youth years, family life and mature years). In addition, the process is tailored to communicate the same messages to all recipients (e.g., government, manufacturers, businesses and public) and those recipients are tasked to filter through that information to educate them. If the straight-line process was created to address all sectors, the complexity and sophistication would be so great that it would be very difficult to manage and deliver educating messages.

14.1 E-waste education strategy 1

The first stage of the educational strategy will be to educate the buyer at the time of the electronic product purchase. Educating the buyer at the time of purchase solidifies a more meaningful message, broadens direct coverage and delivers options to educate your audiences with critical insight and information. Even companies that purchase mass volumes of electronics need to be educated as to their options and process to reduce the impacts of e-waste.

14.2 E-waste educational strategy 2

This stage of the process draws support from the businesses and manufacturers that create and sell the electronic products to the industry. It will be their responsibility to enforce process to educate and deliver valued solutions to all audiences. Implementing additional processes and solutions will automatically add cost to the development and supply chain, so the recommendation is to implement a disposal or educational retainer surcharge to offset the additional expense. Buyer's educational insight will increase when they are paying a surcharge on the products they are purchasing and they may think twice before they inappropriately throw the product away.

14.3 E-waste educational strategy 3

This stage of the process will rely on traditional media channels (e.g., radio, television, newspaper) to deliver high level awareness and create solid branding to the topic. To create such advertising, budget always seems to be an issue; however, the strategy will look to the media companies to give back to the global environment. This strategy will also utilize current non-profit organizations and forums to continue their efforts and support the educating actions.

14.4 E-waste educational strategy 4

This stage labels the internet as the centralized information enterprise to facilitate the global mission and vision related to educating the audiences. Since the internet is the only solution that truly has a global reach for diversified intelligence, it is the best central headquarters for core educating information.

14.5 E-waste educational strategy 5

This stage is the last high level stage of the process; global governments will need to enforce compliancy among channels. This means that the participating governments will be under responsibilities to educate and oversee processes related to e-waste. This strategy will most likely be the component necessary for eliminating the road blocks under strategy 4.

15. E-waste curriculum development strategies

E-waste is considered to be a significant threat to populating the environment and has been described as one of the key pollution issues that need to be addressed under the banner of sustainable development. Educating the population in Sustainable development activities has been a topic that has received considerable attention since the United Nations Decade of Education for Sustainable Development was launched in 2005. UNESCO has released toolkits and learning material that integrate the principles, values, and practices of sustainable development into all aspects of education and learning. It is anticipated that these educational efforts will bring about a changes in behavior to encourage a sustainable future for both the present and future generations (UNESCO 2008).

16. Sustainable engineering: using whole system design concept

Whole System Approach (WSA) is a process through which the inter-connections between sub-systems and systems are actively considered and solutions are sought that addresses multiple problems via one and the same solutions. Teaching the concept of WSA to engineering and design students is vital to ensure cost effective reduction in the current negative environmental impacts of EEE. Engineers and designers need to know how to implement WSA concepts to ensure sustainable designs. Considering the ‘end of life’ process of a product at the design phase will have tremendous benefits to environmental sustainability.

17. Green IT: reducing waste in the IT environment

Green IT is a multi-component approach to establishing and sustainable operating an IT business function. Sustainable IT is becoming increasingly important in the eyes of many organizations. A recent survey of both the government and corporate sectors companies found that 80% of IT decision makers believe that implementing sustainable IT in their organizations is important and 49% cite positive reputation as one of the greatest benefits.

However, 51% of IT decision makers cite cost as a barrier to implementing Sustainable IT technologies, 25% cite complexity of implementation and maintenance, and 21% cite potential disruptions to current IT systems (Stasinopoulos et al., 2007). Another important idea is the concept of product service systems: This concept is also known as sustainable services and systems or eco-efficient services. This concept encourages customers to purchase the services of some or all of their IT hardware and software components through leasing, renting, sharing or pooling while the vendor maintains the ownership, responsibility and stewardship of the products.

18. E-waste education introduction courses

The list of modules shown in Table 2 can be introduced at the high school level or in undergraduate courses through case studies, research projects or group discussion to illustrate the challenges of e-waste in society. These modules can be developed to engage a variety of age bracket. Topics that cover e-waste education on a general level can be introduced into a variety of disciplines such as media, journalism, social sciences and general education courses.

19. Concluding remarks

The overall goal is to guide, educate and implement global techniques and preventative solutions that will help to translate e-waste into safe and reusable forms. It will take the voice and support of people from different countries to implement changes and to address the hard realities of what the environment will be faced with in the years to follow. Education is one of the most important strategies to address e-waste because most people in the developing world are unaware that a problem even exists. However, when the problem is presented with guidance and insight, its importance may be realized. This knowledge along with statistics to support it can be a very valuable resource for implementing strategic plans, addressing future policies and developing laws. The topics and themes presented in this article are examples of innovative approaches to addressing the e-waste educational challenges such as incorporating whole system design concepts into engineering and implementing green IT concepts to reduce waste and infrastructure costs. From a non technology perspective, e-waste education should be incorporated into social sciences such as citizenship classes, journalism, media and general education.

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Notes

Note 1.This is an example.

Table 1: Effects of E-Waste constituent on health –

Source of e-wastes	**Constituent**	**Health effects**
Solder in printed circuit boards, glass panels and gaskets in computer monitors	Lead (PB)	• Damage to central and peripheral nervous systems, blood systems and kidney damage. • Affects brain development of children.
Chip resistors and semiconductors	Cadmium (CD)	• Toxic irreversible effects on human health. • Accumulates in kidney and liver. • Causes neural damage. • Teratogenic.
Relays and switches, printed circuit boards	Mercury (Hg)	• Chronic damage to the brain. • Respiratory and skin disorders due to bioaccumulation in fishes.

Corrosion protection of untreated and galvanized steel plates, decorator or hardener for steel housings	Hexavalent chromium (Cr) VI	• Asthmatic bronchitis. • DNA damage.
Cabling and computer housing	Plastics including PVC	Burning produces dioxin. It causes • Reproductive and developmental problems; • Immune system damage; • Interfere with regulatory hormones
Plastic housing of electronic equipments and circuit boards.	Brominated flame retardants (BFR)	• Disrupts endocrine system functions
Front panel of CRTs	Barium (Ba)	Short term exposure causes: • Muscle weakness; • Damage to heart, liver and spleen.
Motherboard	Beryllium (Be)	• Carcinogenic (lung cancer) • Inhalation of fumes and dust. Causes chronic beryllium disease or beryllicosis. • Skin diseases such as warts.

Figure 1 E-waste disposal strategy-

Figure 2 E-waste educational strategy actors

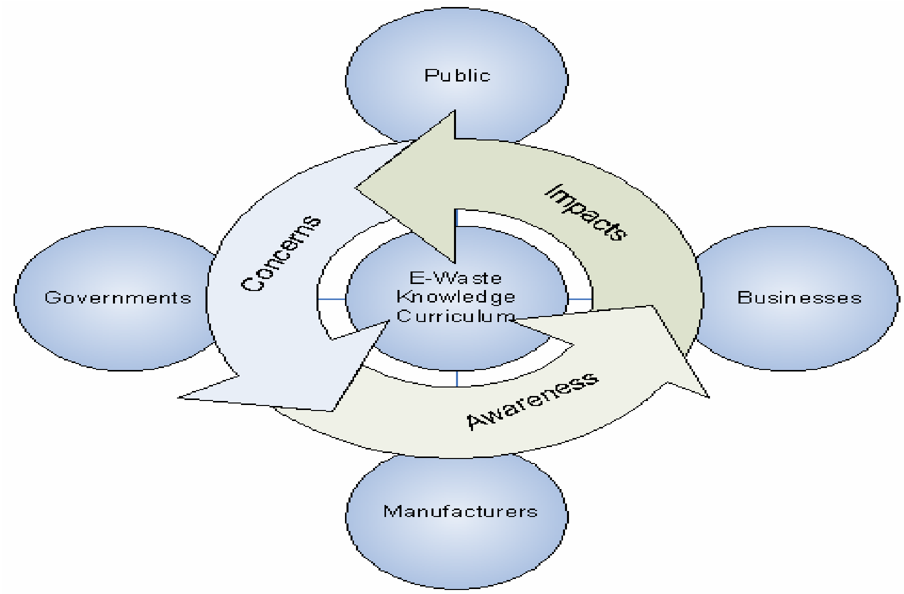
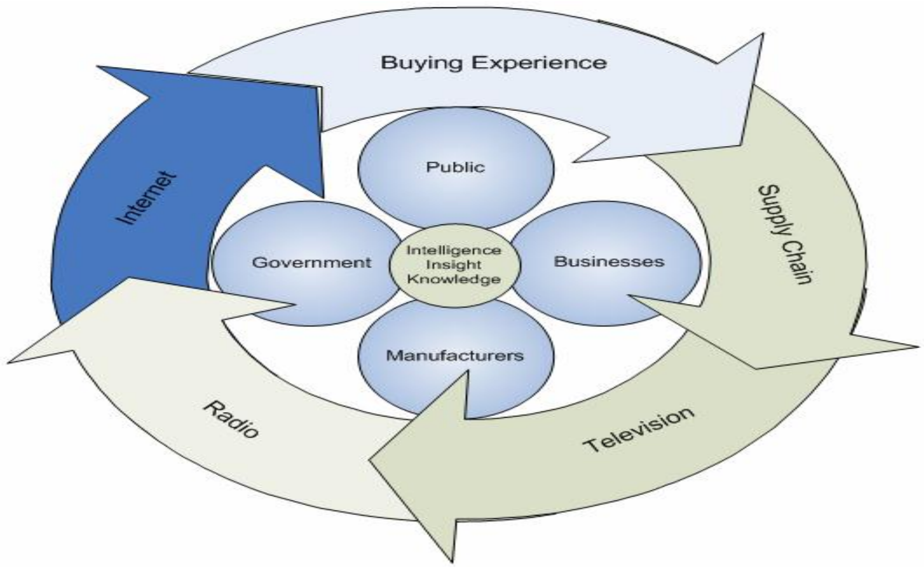


Figure 3 E-waste educational strategy through multiple mediums


Buying Experience
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