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E-WASTE AWARENESS AND PRACTICES OF ZIMBABWEAN UNIVERSITY STUDENTS A DESCRIPTIVE STUDY

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ABSTRACT

Africa's cyberspace is experiencing unprecedented growth as the continent joins the global village to spur socio-economic development. Information and communication technologies (ICT) have become part of everyday life, and when they reach their end of working life, they become electronic waste (e-waste) and should be appropriately discarded. However, the continent is streaming towards a major crisis as obsolete ICT equipment is indiscriminately disposed of to the detriment of the environment and public health. This study aimed to assess university students' e-waste awareness and practices. This cross-sectional study was conducted amongst university students in Zimbabwe. After obtaining institutional ethical clearance, a predesigned pretested questionnaire was administered to university students with informed consent. The sample size calculated was 223 from four purposely selected state universities. Part two and four students were randomly selected. Chi-square Test was applied to get the Chi-square value and p-value. Multiple regression analysis was used to determine the significance of the independent variables in explaining the variability of the dependent variable. Our results show that the four independent variables (lack of knowledge, policies, poor practices and handling) positively influenced e-waste management by university students in Zimbabwe. Of the four independent variables, poor handling had the strongest effect on e-waste management with a regression coefficient of 0.420 and the lowest significance of 0.000. Although the knowledge of e-waste was high, students lacked knowledge of policies/laws that regulate environmental and health management. Advanced knowledge of e-waste did not translate into responsible management as e-waste was kept at home, transported and stored with municipal waste, and there were no designated bins for collecting it. Most respondents were unsure of what was happening regarding the generation, handling, storage, transportation and final disposal of e-waste. By analyzing students' knowledge and practices, universities should intensify e-waste management advocacy by incorporating e-waste matters into their learning curriculum. The government should enact policies that govern the management of e-waste, and this will provide a framework for institutions to set up local-level policies that promote green initiatives.
Keywords: *Health Information, University Students, E-Waste Management, Awareness, Practices*

1. INTRODUCTION

Africa's cyberspace is experiencing unprecedented growth as the continent joins the global village to spur its socio-economic development. Information and communication technologies (ICT) and other electronic devices have become part of everyday life. After use, broken down, or after a newer version, these devices become obsolete and are discarded as electronic waste (e-waste). E-waste is classified among the top hazardous solid waste streams globally. Baldé et al. estimated that the world would produce 53 metric tons of e-waste by 2020; Sthiannopkao and Wong estimated that the global e-waste output would reach 65 metric tons in 2023 [1] [2]. The cost of recycling e-waste in line with environmental and health considerations is very high in developed countries, and therefore, e-waste is frequently shipped to developing countries where there are no policies to protect the environment.

Countries with high informal e-waste recycling activities, such as China, Nigeria and Ghana, have reported that up to 20% of farmland and grazing land is polluted [27]. Lakes, rivers and other water bodies near dumpsites are contaminated, affecting marine life and plants. Human fatalities are reported from consuming plants and aquatic animals near the dumpsites.

E-waste accumulation is fueled by the reduced life span of ICT devices; in the 90s, the life span of desktop computers was about ten years, and this has reduced to 3-4 years, while laptops have a lifespan of two years and 3-5 years for printers and photocopiers [6]. Coleman notes that the life span of two years for computers fuels e-waste accumulation as universities replace computers more frequently than before [7]. Higher education institutions frequently replace computer equipment that has reached its lifespan with new ones to achieve their administrative and teaching objectives. At a 5% annual growth, e-waste is the leading solid waste stream and grows three times faster than municipal waste [5] [8] [9]. Sajid et al. also reported that e-waste constituted 10% of global solid waste and grew at an alarming rate of 3 times more than solid waste [10].

2. LITERATURE REVIEW

Developing countries are leading in adopting ICTs to participate in the global knowledge economy, and the United Nations Environment Programme (UNEP) predicted that South Africa and China would experience a 500% increase in e-waste levels by 2023 when compared to 2007 levels [11]. Due to the non-availability of electricity in most rural areas, some donated computers quickly reach obsoleteness before use, and those that break down cannot be repaired due to a lack of facilities and skills, fueling e-waste [12].

Most of the e-waste exported to developing countries is unusable; Asante and Edumadze et al. lamented that Sub-Saharan Africa, like most developing countries, is increasingly becoming the digital dumpsite for the developed countries [3] [4]. Similarly, Kitila noted that most of the electronics imported into most developing countries were useless junk and indiscriminately treated by informal recyclers who disregard environmental protection and human health concerns [5].

There is concern that e-waste generation is growing faster than efforts to manage its environmental and human health impact [27]. The toxic substances in e-waste include lead, nickel, cadmium, chromium, beryllium, lithium, mercury, and many others, whose unsound management is catastrophic to the environment and human health [13]. Developing countries lack the finances and infrastructure to manage e-waste; its management is unlicensed and unregulated, where primitive techniques such as burning, leaching, and heating are practised, negatively affecting the environment and public health [28].

Even though most developing countries have small quantities of internally generated e-waste, the bulk comes through illegal exports. In increasing access to the Internet, reducing the digital divide, and participation in the global village, developing countries like Zimbabwe continue to receive donations of used ICTs and procure cheap used ICTs from the West [14]. Amankwah-Amoah reports that most imported electronics are mixed with unusable and unrepairable equipment and are indiscriminately disposed of, threatening the environment and human health [9]. Just like in other developing countries, e-waste management has not been given sufficient attention in Zimbabwe, and therefore, there are no policies or strategies for its management [15].

The number of universities has increased by about 65%, from 17,036 universities in 2009 to 28,077 universities in 2018 [16]. High student populations result in high usage of computers; thus, levels of e-waste have increased. Higher Education Institutions (HEI) constantly integrate ICTs such as the Internet, artificial intelligence, and the Internet of Things to support 21st-century learning needs. Most institutions buy cheaper computers from Computer Aid and Worldloops to bridge the digital divide and enable their students to connect to the digital superhighway, thus significantly contributing to the e-waste burden [17]. Most developing countries have reviewed their curricula in line with the demands of the knowledge economy. In Zimbabwe, Education 5.0 has been introduced to support innovation and industrialization, prioritizing automation and the deployment of intelligent-driven systems. [18]. This leads to more adoption of computer-related devices to drive the fourth industrial revolution. HEIs have seen massive enrollments as more universities are established in Zimbabwe.

The study examines the knowledge, attitudes and practices of university students in Zimbabwe regarding e-waste management. The study also raises awareness of the sustainability of natural resources and advocates for integrating e-waste management into the university curriculum. The basis of the study is supported by Olafisoye et al., who noted that education, awareness and practices were crucial to managing e-waste effectively [19]. These findings might offer reference information on e-waste management in Zimbabwe and effective e-waste management programs by researchers and other stakeholders.

Positive knowledge, availability of policies and appropriate handling and practices among university students result in better e-waste management strategies that ensure the sustainability of the environment and human health. The study, therefore, came with the following hypotheses.

Hypothesis 1: Lack of knowledge positively influences improper management of e-waste.

Hypothesis 2: Lack of policies positively influences improper management of e-waste.

Hypothesis 3: Poor practices positively influence improper e-waste management.

Hypothesis 4: Inappropriate handling positively influences improper e-waste management.

3. METHODS AND MATERIALS

3.1 Study Setting

The study was conducted at four state universities in Zimbabwe purposively selected. Zimbabwe is a landlocked country in Southern Africa between Zambezi and Limpopo rivers and is bordered by South Africa, Botswana, Zambia, and Mozambique. Based on the Census of 2012, the country's total population was 13,061,239 [20]. Of the population, 6,280,539 are males and 6,780,700 females, giving a sex ratio of 91 males per 100 females. The majority of the population has low socio-economic status and average education. Zimbabwe has 13 state-controlled and eight private universities, several technical and teachers' colleges, and vocational training centres across the country's ten provinces. Most universities offer computer science or information technology (IT) and environmental science degrees and have active environmental clubs engaged in environmental management initiatives on the campus and in surrounding communities. Universities are actively involved in high-tech processes as part of the learning curriculum, thus potential generators of e-waste. It is crucial to understand the issues related to e-waste management so that proper and sound management and monitoring initiatives can be taken to ensure proper measures are in place. Inappropriate management of e-waste in institutions could jeopardize the country's public and environmental health. Furthermore, the output of this study can be used as a benchmark for other universities and institutions in Zimbabwe and the region that share the same characteristics.

3.2 Study Design and Population

A cross-sectional study was conducted between October 2021 and February 2022, employing a sequential analytical approach while collecting quantitative data. Quantitative data were collected to give insights into the results based on the survey and statistical tests. The study population comprised students in parts two and four studying IT/computer science and environmental science degrees aged 18 years and above.

3.3 Sample size

Students were sampled from four purposively selected universities. Only those students who consented to the study were included. Random sampling was conducted to select eligible students for the study within the program. The Raosoft sample size calculator was used to determine the sample size at a confidence level of 95%, a margin of error of 10%, and a response distribution of 50%. Based on the Raosoft sample size calculator, the sample for students was as follows; University A (84), University B (30), University C (50), and University D (59) to make a total of 223 students. Part one and postgraduate students and those doing programs unrelated to e-waste management were excluded from the semi-structured questionnaire study.

3.4 Study tool

A pretested semi-structured questionnaire was employed. The researchers designed the questionnaire based on similar e-waste management research. It contained questions about knowledge levels, environmental and health effects, and practices such as disposal and storage methods. The questionnaire utilized open and closed-ended questions to assess students' knowledge and practices regarding e-waste

management at the selected universities. The reliability of the questionnaire was confirmed by distributing it among ten students for a pilot study. The questionnaire was comprised of three sections. The first section contained the demographic profile of the respondents (gender, age, level of education, and others). The second section measured the student's knowledge of e-waste and its management at the university campus. The third section sought to understand the practices of the students and their institutions regarding e-waste management and recycling. The student's knowledge and perceptions were presented in percentages and proportions.

3.4 Data Analysis

The descriptive and analytical statistics of the data collected were assessed using STATA software (version 25.0). The data were tested firstly for outliers and normality of distribution using skewness and kurtosis indices. The parameters calculated include percentages and frequencies. The statistical analysis also included cross-tabulations to test the relationship between institutions and students' knowledge and practices. Chi-square Test was applied to get the Chi-square value and p-value. The level of significance was set at $p < 0.05$. Multiple regression analysis was employed to determine the significance of the four independent variables on the dependent variable.

3.5 Ethical Approval

Permission to conduct the study was granted by university authorities. The Medical Research Council of Zimbabwe approved this study with an approval code MRCZ/A/2811. Written informed consent was obtained from all participants. Participation in the study was voluntary. Data were treated with maximum confidentiality by storing it in password-protected computers only accessed by the principal investigator and authorized research team members.

4. RESULTS

4.1 Demographic characteristics of Respondents

A total of 223 students from four universities were studied, and 51.1% of the respondents were females. The age groups ranged from 20 years to 54 years. The distribution of the respondents by the institution is shown in Table 1, with most students (37.7%) coming from institution A and the least (13.5%) coming from institution C. This was based on the number of students in the target departments per institution. Of the 223 respondents, 26% were student leaders, and 46% were club members. Most of the students (75%) had been with the institutions for 2 to 4 years; 62% were part 2s, while the rest were part 4s.

Table 1: Distribution Of Respondents According To Institutions

Variable	Category	Number	Percentage (%)
Sex (N=223)	Male	109	48.9
	Female	114	51.1
Age in years (N=220)	<25	130	59.1
	25-34	59	26.8
	35-44	28	12.7
	45-54	3	1.4
Institution (N=223)	A	84	37.7
	B	30	13.5
	C	50	22.4
	D	59	26.5
Student leader (N=220)	Yes	56	25.5
	No	164	74.5
Period at institution (N=223)	<2	59	26.5
	2-4	146	65.5
	>=5	18	8.1
Level (N=102)	Part 2	63	61.8
	Part 4	39	38.2
Club member (N=215)	Yes	99	46.0
	No	116	54.0

4.2 Knowledge about e-waste among university students

Most (80.7%) students had a basic knowledge of e-waste, while 193 (94.2%) students could adequately describe e-waste. Students accessed e-waste information from diverse sources, which included the Internet (60%), formal lectures (14.1%), books (4.9%), radio/TV (3.4%), workshops (2.4%), other sources (5.9%) and 9.3% have never heard about e-waste. Results show that the Internet was the largest source of information regarding e-waste. Students were asked to describe the effects of indiscriminate disposal of e-waste on the environment. About sixty percent (60.8%) did not know the effects on the environment, while 17.2% mentioned pollution, 12.4% chose global warming and 9.6% selected soil contamination. Regarding the effects of e-waste on public health, 70% were unaware of health problems associated with e-waste, 23.2% indicated respiratory illnesses, and 4.6% mentioned cancers. Regarding e-waste policies, 73.6% of the students were unaware of any policies governing the management of e-waste, and 26.4% indicated that they were aware of some policies.

4.3 Practices on E-waste among university students

Students were asked if they had ever handled electronic waste; the majority (57%) indicated that they had never handled this type of waste. Fifty-five percent of those that had handled e-waste highlighted that it was not separated before storage, and therefore, there were no special storage facilities for this type of waste. When asked about the practices at their institutions, most respondents (58%) were unsure of what was happening regarding the generation, handling, storage, transportation and final disposal of e-waste.

Those who were aware of e-waste management activities at the university were further asked to estimate the amount of e-waste generated at their institutions. Most of them (39%) were unsure of the waste generated, 20% selected less than 50kgs and 19% chose over 500kgs, as shown in Table 2. Table 3 shows the responses to the questions about separating e-waste during storage and transportation.

Table 2: Distribution Of Respondents Concerning The Amount Of Waste Generated By Institutions

Amount of waste generated by the weight	Number of Respondents	Percentage of responses
<50kg	35	20
50-100kg	26	15
101-500kg	12	7
>500kg	33	19
Do not know	68	39

Table 3: Separation Of E-Waste During Storage And Transportation

Is the waste separated during storage? (N=217)	Yes I do not know No	1 0 0	77 (35.5) 70 (32.3) 70 (32.3)
Is the waste separated during transportation? (N=216)	Yes I do not know No	1 0 0	60 (27.8) 84 (38.9) 72 (33.3)
Is the waste separated during disposal? (N=214)	Yes I do not know No	1 0 0	71 (33.2) 75 (35.0 68 (31.8)

Over a third (35.5%) of respondents indicated that e-waste was separated during storage, while 38.9% (most respondents) did not know if there was separation during transportation and disposal. Another 32.3% indicated that e-waste was not separated during transportation. Only 33.2% of

the students agreed that their institution separated e-waste during disposal, while 35% did not know, and 31.8% indicated that there was separation.

4.4 Association of student knowledge variables with their universities

Cross-tabulations to test relationships between knowledge level and the different institutions were performed. When the participants were asked about e-waste, respondents from institution A showed a higher knowledge level (33.8%), followed by institution D (28.8%). Both institutions C and B showed a low knowledge level with 20.6% and 16.9%, respectively. These differences per institution were statistically significant, as confirmed by a p-value of 0.032. Measures to improve the general e-waste knowledge among students, especially at institutions with insufficient knowledge, must be recommended.

Table 4 shows the general knowledge and environmental and health effects of e-waste according to the different institutions. Institution A has the highest number of respondents, 57 (35%), who agreed that e-waste affects public health and the environment. Institution D had a knowledge level of 28.2%, and B recorded the least knowledge level of 16.2%. In this section, the knowledge that e-waste causes public health and environmental problems has a p-value <0.05 (p-value = 0.045). This indicates that the knowledge of respondents differs significantly depending on their institutions.

Table 4: Distribution Of Subjects According To Their Knowledge Of The Term E-Waste

Criteria	Responses	Knowledge about e-waste		Total	P-value
		Yes	No		
Have you ever heard about the term e-waste (N=198)	A B C D	54 (33.8%) 27 (16.9%) 33 (20.6%) 46 (28.8%)	20 (52.6%) 2 (5.3%) 3 (7.9%) 13 (34.2%)	74 (37.4%) 29 (14.6%) 36 (18.2%) 59 (29.8%)	0.032
Do you know that e-waste causes environmental and public health problems? (N=198)	A B C D	57 (35.0%) 27 (16.6%) 33 (20.2%) 46 (28.2%)	20 (52.6%) 2 (5.3%) 3 (7.9%) 13 (34.2%)	77 (38.9%) 29 (14.6%) 36 (18.2%) 59 (29.8%)	0.045

4.5 Regression analysis

A regression test was used to evaluate the extent to which the independent variables predict the dependent variable. Table 5 shows the four independent variables (lack of knowledge, policies, poor practices and inappropriate handling). The value of R is 0.860, and the value of R Square is 0.675.

4.5.1 Test of significant

The significant value for lack of knowledge is 0.190, as shown in Table 5, and the value is less than 0.050. Thus H_1 is accepted, meaning that lack of knowledge significantly contributes to poor e-waste management. Table 5 shows a significant value of 0.001 for lack of policies, which is less than 0.050. H_2 is accepted, this means that lack of policies has a significant relationship to e-waste management by students. There is a significant value of 0.001 for poor practices, which is less than 0.050. Therefore, H_3 is accepted, meaning poor practices are a significant barrier to implementing e-waste management. Similarly, there is a significant value of 0.000 for poor handling, which is less than 0.050. This implies that H_4 is accepted; thus, poor handling is a significant barrier to implementing e-waste management. Poor practice is the independent variable that most significantly affects e-waste management, with a regression coefficient of 0.420. The other significant independent variables are poor practices (0.370), lack of policies (0.240) and lack of knowledge (0.190).

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Table 5: Multiple regression analysis (dependent variable: the barrier to implementing e-waste management)

	Unstandardized coefficients			
Variable	**B**	**Std Error**	**t**	**Sig.**
Lack of knowledge	0.190	0.82	2.338	0.027
Lack of policies	0.240	0.70	3.568	0.001
Poor practices	0.370	0.21	3.245	0.001
Poor handling	0.420	0.92	5.058	0.000

5. DISCUSSION

The study assessed university students' knowledge levels and practices regarding e-waste management. The study adds new knowledge to the existing literature on the sustainable management of resources. University students are the most influential ICT users; therefore, they must embrace green initiatives to mould their attitudes and practices for properly managing the resultant e-waste. The current study's results indicate that most universities do not have a multi-disciplinary course covering e-waste as most students learnt about e-waste through the Internet. Most students did not know of the hazardous chemicals in e-waste; this is similar to a study by Deniz et al., who observed that only 22% of Indian university students could classify hazardous materials in e-waste [21]. This has a bearing on the e-waste management practices of the students.

The study results show that most students had a basic knowledge of e-waste. The results are similar to a study by Singh et al. across five institutions in Nepal which established that students were aware of e-waste [22]. Most students were unaware of the environmental and health effects of indiscriminate disposal of e-waste. This may be attributed to a lack of curriculum, appropriate collection points, and management of e-waste at the universities. The finding is in line with Raudha and Msolla's work, which established that Tanzanian universities did not have a special curriculum targeting the management of e-waste, which affected students' knowledge levels [23].

The student's lack of awareness of the health effects of indiscriminate disposal of e-waste is consistent with a study by Owojori et al., who established that most university students in South Africa were unaware of the effects of e-waste on health outcomes [24]. A similar study in Nigeria targeting university students established low and unsatisfactory knowledge levels regarding the effects of e-waste on the environment [25].

Fifty-five per cent of those that had handled the waste did not separate it before storage; therefore, there was no special storage for this type of waste. This could be due to a lack of policies; therefore, e-waste is not separated during collection and disposal as there is no motivation for doing so. Our results are similar to those of Ogbomo et al., who observed that the lack of national and institutional policies negatively affected the management of e-waste at a university in Nigeria [26]. Due to a lack of handling facilities, most students could not estimate the amount of e-waste generated by their institutions and were unsure of what was happening regarding the generation, handling, storage, transportation and final disposal of e-waste. Although most respondents knew about e-waste, this knowledge did not translate to responsible management practices, as indicated by the study results.

The results show that universities had not embraced innovative e-waste management practices such as take-back schemes, separation during transportation and storage, and in-house recycling. Therefore, this study raises public knowledge and awareness and promotes sustainable development by advocating for separating e-waste from solid waste during disposal, thereby averting the growing public health and environmental catastrophe.

From the literature reviewed, this is the first national study aimed at creating awareness and targeting university students in Zimbabwe. This is vital in understanding the millennials' e-waste management practices. Through environmental management clubs, universities will become more conscious of e-waste management and develop policies and procedures for managing e-waste. This will increase e-waste collection and management. As e-waste becomes an increasingly important aspect of the university campus, the

results of this study should be used to shape the curricula and national and institutional policies.

6. RECOMMENDATIONS

The knowledge and positive practices on e-waste can be enhanced by adding topics and hands-on activities regarding e-waste in the curricula. The use of social media in disseminating information on e-waste must be enhanced at schools and colleges. Future research could focus on the effectiveness of social media in information dissemination and raising awareness of the environmental and health effects of e-waste. Empowerment and training of environmental clubs at universities must include the management of e-waste. Positive behaviour towards the management of e-waste must be developed among students from the early years of school to university. The government should enact policies that govern the management of e-waste, and this will provide a framework for institutions to set up local-level policies that promote green initiatives.

7. CONCLUSION

This study aimed to assess university students' e-waste awareness and management practices. Results reveal that the respondents were knowledgeable about e-waste and its sources at their institution. Participants had insufficient knowledge of the environmental and public health effects of e-waste. Lack of adequate knowledge of the health and environmental effects of e-waste by university students remains a significant barrier to effective e-waste management. This is a significant concern as e-waste is classified among the top hazardous waste streams globally and has the fastest growth rate [28].

Our study considered four independent variables that affect e-waste management by university students in Zimbabwe: lack of knowledge, lack of policies, poor practices and inappropriate handling. From the four variables, poor handling strongly influences e-waste management, as shown by the lowest significant value of 0.000. All four independent variables have a positive effect and significantly contribute to e-waste management challenges experienced by university students in Zimbabwe.

The high level of awareness did not translate into responsible management of e-waste. The respondents preferred methods of disposal that were convenient for them, and some preferred keeping their old gadgets at home. The university curricula did not adequately address e-waste, as indicated by most students who obtained information on e-waste from the Internet. The knowledge of policies pertaining to e-waste was very scanty, which may explain the poor handling and lack of separation during transportation and disposal. Generally, the practices in the management of e-waste were improper. Most respondents felt that the country should have policies that deter improper management and disposal of e-waste.

AUTHOR CONTRIBUTIONS

VM conceptualized, designed, prepared the manuscript and did the literature search; JM was responsible for data acquisition, DZ did data analysis and statistical analysis, and MM was responsible for manuscript editing and review.

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