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Green Computing Knowledge among Students in a Ugandan University

Isa Semakula
Kulliyyah of Information & Communication Technology
International Islamic University Malaysia
Kuala Lumpur, Malaysia
+256704183613
issemak@gmail.com

Suhaila Samsuri
Kulliyyah of Information & Communication Technology
International Islamic University Malaysia
Kuala Lumpur, Malaysia
+60126940941
suhailasamsuri@iium.edu.my

***Abstract*—Humans, including students, are partly responsible for rising levels of global warming through unsustainable computing practices. It is imperative that students participate in the global drive to reduce global warming through activities like green computing which advocates for sustainable use of computing resources to reduce energy consumption and carbon emissions. The study was conducted to establish green computing awareness levels of students from Islamic University in Uganda (IUIU) and also determine if such levels were influenced by computer experience. Results from a purposive sample of 452 students indicated that students' levels of green computing awareness were low, and computer experience influenced two of the three dimensions of perceived knowledge of green computing.**

Keywords—Green computing, Green IT, Computer experience, Carbon footprint, e-waste, IUIU

I. Introduction

The use of Information Technology (IT) helps to power businesses by creating an enabling environment that provides maximum data storage, retrieval, and communication between various geographically distributed entities. However, the same IT is responsible for the massive electronic waste that is disposed of increasingly as more and more computing hardware are put to use. Green Computing (GC) advocates for the use of IT in an environmentally sustainable way through optimizing energy efficiency for the lifetime of the product while mitigating use of hazardous materials, and encouraging recyclability of computing devices and waste from factories [1].

Uganda is one of the sub-Saharan African countries that fully liberalized their Information and Communication Technology (ICT) industry to promote rapid ICT uptake and competitiveness [2]. As a result, the rate of adoption of mobile ICT services, powered by high-speed broadband Internet connection, is accelerating and helping to address the digital divide. However, the percentage of the African population that has access to the Internet is still below 20%, a big margin compared to 30% possessed by the South East Asian countries [2].

It was until 2012 that the government of Uganda [3] came up with an e-waste policy document that laid out strategies, the institutional framework, and monitoring and evaluation procedures for managing e-waste in Uganda. Although computer usage has been reported to be growing given that the government, Non-Government Organisations and education institutions in Uganda take up approximately 75% of the total computer users in the country [4], currently, one cannot establish with certainty the extent to which computer users in Uganda are informed about, and practising the recommended principles of Green IT.

University students are the future leaders, decision makers and policy implementers of their respective communities, economically, socially, politically and environmentally [5]. Their behaviours and knowledge is important for causing change towards having a society conscious of its environment. Thus, by investigating Green computing knowledge levels among university students, this study is founded on the basis of students' role as agents of change in society.

Unlike break-through scientific advancements, climate change control efforts like Green Computing are not a responsibility of a single person or group of individuals but require the collective action of the entire global population [6], [7]. Students from high institutions of learning represent a sizeable percentage of overall computer users and, thus, are agents of human activities that generate carbon emissions through unsustainable computing practices. Given that knowledge is a necessary driver of behavior, it is important to establish how much students know about the subject of Green computing. Whereas a number of researchers have studied the awareness levels and other factors that impact students' knowledge and awareness of Green computing, it is unknown whether computer experience influences their levels of green computing perceived knowledge. Previous studies looked at field of study and gender in exclusion of one's computer experience. Yet computer experience has been reported to have an impact on students' levels of computer literacy [8]. Moreover, no studies about green computing awareness and knowledge have been conducted in the context of Uganda.

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The study, therefore, was an attempt to fill the above mentioned gap in the literature by investigating green computing perceived knowledge among students from a Ugandan university and finding out if it was influenced by computer experience.

II. Related Literature

A. Green Computing

Green computing has been defined as activities that involve efficient use of computing resources, through less use of materials that are harmful, ensuring that energy is conserved for products throughout their usage time, and efficient handling of electronic waste through recycling [9]. Green computing is part of a comprehensive corporate sustainability program that aims at achieving the triple bottomline of preserving the economic, environment and social systems[10], [11]. The benefits that accrue from the practice of green computing comprise a reduction in the overall consumption of energy, cost minimization, mitigation of environmental impact and carbon footprint, efficiency in the use and performance of systems, and improved space use [12].

The recommended practices of green computing include dematerialization of IT products and services by providing substitutes that have very low carbon footprint [6]; refurbishing, re-using and recycling old hardware [12]; eco-friendly cooling systems for data centers; and use of sstandards bodies to issue certificates of compliance and eco-labels on manufactured products [13].

B. Awareness and Practice in Uganda

Although there are many campaigns to educate the masses about their environment, Uganda still lacks a meaningful number of empirical studies conducted to reveal the level of public awareness and behavior in achieving a sustainable environment. A study conducted by the BBC World Service Trust [14] indicated that majority of Ugandans acknowledged that climatic changes are as a result of human behavior. However, they exhibited less knowledge regarding global warming and changes in the climate. While they referred the latter to mean changes in seasons and weather conditions, their perceptions were hinged on existing knowledge and traditional conceptions such as God, deforestation, smoke pollution, and high population, especially among the rural population and women [14].

The National Environment Management Authority (NEMA) was established and mandated to raise environmental awareness and increase public participation through activities like publishing reports about the state of environment, facilitating dialogues among the public, training programs and provision of digital information in the NEMA library [15].

With the influx of personal computers and more so, mobile smartphones in Uganda of recent, public awareness can be greatly enhanced by leveraging these technologies. A previous study conducted indicated that ICTs are the leading means of communication of information about sustainable environmental policies [16]. The ministry of ICT devised a policy to manage e-waste as a step towards addressing the problems related to electronic waste handling in the country. The policy is guided by the need to provide protection for humans and the environment, and end-user awareness in handling e-waste [3], [4].

Both formal and informal computer refurbishment exist in Uganda, with the latter being dominant [4]. The informal industry includes small-sized companies and individuals that do computer servicing like operating system upgrades and hardware parts replacement [4]. On the other hand, formal refurbishment in Uganda has been taken up by a few professional companies. They import used computers, refurbish and sell them at affordable prices compared to new computers [4].

C. Green Computing Knowledge

The theoretical framework of the study was premised on the works of Ahmad and Nordin [17] that investigated the green computing perceived knowledge of students in relationship with their behavior towards sustainable environment. They posited that the concept of green computing perceived knowledge is a multidimensional construct comprising of the understanding of green computing vocabulary, the nature of computers and the management of electronic waste [17]. Their work is based on Murugesan's [12] holistic approach to Green computing that highlighted several dimensions of the subject.

Environmental knowledge can be measured by self-rated (subjective/perceived) knowledge and actual (objective) knowledge [5]. Perceived knowledge indicates the level at which a person thinks he/she knows about the subject [5]. It is the extent to which a person reports about himself/herself knowing a particular phenomenon [17]. It is argued that one's level of subjective knowledge, especially acquired through direct experience, has a profound impact on their sustainable environmental behavior [18].

In a recent study, field of study, (ICT or non-ICT field), was reported having an impact on both objective and perceived green computing knowledge among university students [19]. The results indicated that ICT-based students were far better than their non-ICT counterparts in both objective and subjective green computing knowledge.

While the number of studies conducted to establish the influence of field of study (ICT or non-ICT) on green computing knowledge among students are very few, similar studies that investigate students' computer experience and its impact on what they know about green IT are almost non-existent. However, it is believed that the level of computer experience possessed by students influences their knowledge in ICT-related fields. A study conducted at a Malaysian uni-

versity revealed that students with more computer experience also exhibited higher computer literacy levels [8]. It was, therefore, important that computer experience be studied to ascertain its influence on green computing awareness among students.

III. Methodology

A. Sampling

Using a cross sectional survey, the study was conducted at Islamic University in Uganda, main campus located in the Eastern region of Uganda. The study involved students of both ICT and non-ICT based programs from which a purposeful sample [23] of 500 respondents was drawn. Out of the 500 questionnaires distributed, 452 were returned and used in the study, yielding a response rate of 90.4%. Male respondents were 257 (53.9%) while females were 195 (46.1%).

ICT respondents were 230 (50.9%) drawn from Faculty of Science, majority of them pursuing Bachelor of Information Technology (40.9%). Others offered Bachelor of Computer Science (4.4%) and Diploma in Computer Science and IT (5.5%). Non-ICT respondents were 222 (49.1%) from four faculties, i.e. Faculty of Arts and Social Sciences, Faculty of Law, Faculty of Management Studies and Faculty of Science. These were pursuing Bachelor of Laws (13.5%), Bachelor of Development Studies (8.2%), Bachelor of Science in Mass Communication (8.8%), Bachelor of Social Works and Social Administration (10.4%), Bachelor of Human Resources Management (4%), Bachelor of Public Administration (.6%) and Bachelor of Statistics (3.5%).

Computer experience was categorized into two groups namely; "Low Experience" and the "High Experience". The low experience category included 209 (46.2%) respondents with 1 to 2 years of computer experience while the high experience group constituted 228 (53.8%) students with computer experience of 3 years and above. The two categories involved respondents from both ICT and non-ICT groups.

B. Instrumentation and Measurement

The survey instrument used was validated in a previous study conducted in Malaysia [17], whose findings formed the theoretical underpinning of this study. The same instrument had also been used in two other studies related to green computing knowledge and awareness among university students [19], [22].

Green computing perceived knowledge had 3 factors, each measured by 4 items on a five-point Likert scale (i.e. "none", "low", "moderate", "quite high", "high"). The factors were "Vocabulary", measured by "Green PC", "Carbon footprint", "Carbon-free computing" and "E-waste". The second factor was "Nature of computers", measured by "Negative environmental effect of computers", "Energy consumption levels of computers", "Poisonous chemicals used to produce computers" and "Computer power saving features". The third and last factor was "E-waste management" that was measured by "E-waste management organisations", "E-waste management programs", "EPEAT-certified products" and "Hardware recycling programs".

C. Data Analysis

Using SPSS statistical package, a reliability analysis was conducted to establish the internal consistency of the items for each factor. It was followed by descriptive analysis of the captured data to address the first objective.

A set of three independent samples t-tests were conducted to determine the influence of computer experience on green computing perceived knowledge by finding out if the mean differences between the groups was significant.

IV. Results And Discussion

A. Factor Loadings and Reliability Analysis

Using a sample of 452 students, exploratory factor analysis was conducted that yielded three factors as shown in table 1 below.

Table 1. Summary of Factor Loadings and Reliability Analysis

Factor	Items	Alpha	M	SD	Factor Loading
Vocabulary	"Green PC"	.71	1.20	.59	.64
	"Carbon footprint"		1.24	.62	.84
	"Carbon-free computing"		1.24	.64	.83
	"E-waste"		1.22	.62	.59
Nature of Computers	"Environmental effect of computers"	.73	3.34	1.19	.79
	"Energy consumption levels of computers"		3.28	1.20	.77
	"Poisonous chemicals used to produce computers"		3.31	1.19	.71
	"Computer power saving features"		3.34	1.12	.68
E-waste Management	"E-waste Mgt Organisations"	.72	2.16	1.14	.74
	"E-waste Mgt Programs"		1.92	1.10	.77
	"EPEAT-certified Products"		1.94	1.04	.69
	"Hardware Recycling Programs"		2.02	1.12	.73

Using Principal Component Analysis (PCA) with Direct Oblimin axis rotation method, three factors were extracted with total variance explained value of 55.29% (Green computing vocabulary: 25.34%, Nature of computers: 16.53%, and E-waste management: 13.42%). Kaiser–Meyer–Olkin measure established the sampling adequacy, KMO = .74. Bartlett's test of Sphericity χ^2 (66) = 1238.36, $p < .001$, indicated that correlations between items were sufficiently large.

B. Perceived Knowledge Levels

1) Vocabulary: The overall statistics for the terminologies of green computing indicate that levels of knowledge are extremely low with mean M = 1.225 and a standard deviation SD = .577.

Table 2. Vocabulary Knowledge Levels

Item		Computer Experience		Overall
		Low	High	
"Green PC"	M	1.11	1.29	1.20
	SD	.432	.697	.574
"Carbon footprint"	M	1.20	1.27	1.24
	SD	.559	.668	.617
"Carbon-free computing"	M	1.19	1.28	1.24
	SD	.565	.492	.525
"E-waste"	M	1.10	1.33	1.22
	SD	.405	.754	.592
Overall	M	1.147	1.292	1.225
	SD	.490	.652	.577

Table 2 shows students with high computer experience being consistently dominant over those with low experience for all items measuring vocabulary i.e. "Green PC" (High experience: M = 1.29, Low experience: M = 1.11), "Carbon footprint" (High experience: M = 1.27, Low experience: M = 1.20), "Carbon-free computing" (High experience: M = 1.28, Low experience: M = 1.19), and E-waste (High experience: M = 1.33, Low experience: M = 1.10). Of the four items, students were slightly more familiar with carbon footprint (M = 1.24, SD = .617) and carbon-free computing (M = 1.24, SD = .525) followed by E-waste (M = 1.22, SD = .592) and lastly Green PC (M = 1.20, SD = .574).

2) E-waste Management: From Table 3, the overall mean for e-waste management self-rated knowledge was M = 2.009 and a standard deviation of SD = 1.106.

Table 3. E-waste Management Knowledge Levels

Item		Computer Experience		Overall
		Low	High	
"E-waste Mgt Organisations"	M	2.12	2.20	2.16
	SD	1.098	1.190	1.148
"E-waste Mgt Programs"	M	1.89	1.96	1.92
	SD	1.081	1.116	1.100
"EPEAT-certified Products"	M	1.81	2.04	1.94
	SD	.950	1.113	1.046
"Hardware Recycling Programs"	M	2.03	2.00	2.02
	SD	1.124	1.135	1.129
Overall	M	1.962	2.05	2.009
	SD	1.063	1.138	1.106

Table 3 indicates that students were slightly more knowledgeable about "e-waste management organizations" (M = 2.16, SD 1.148), followed by "hardware recycling programs" (M = 2.02, 1.129), then "EPEAT-certified products" (M = 1.94, SD = 1.046) and lastly "e-waste management programs" (M = 1.92, SD = 1.100). Surprisingly, students with high computer experience reported slightly more knowledge levels on only three items, i.e. "e-waste management organisations" (High experience: M = 2.20, Low experience: M = 2.12), "e-waste management programs" (High experience: M = 1.96, Low experience: M = 1.89) and "EPEAT-certified products" (High experience: M = 2.04, Low experience: M = 1.81). Students with low computer experience reported slightly more knowledge levels for the item "hardware recycling programs" (High experience: M = 2.00, Low experience: M = 2.03).

3) *Nature of Computers:* Unlike vocabulary and E-waste management factors, students' self-rated levels of knowledge for the "nature of computers" were above the overall hypothetical mean of 2.50. Table 4 shows that the overall mean statistic M = 3.317 were superior over other two dimensions (vocabulary and e-waste management). Students were slightly more familiar with "computer power saving features" (M = 3.34, SD = 1.125) and the "environmental effect of computers" (M = 3.34, SD = 1.199) followed by "poisonous chemicals used to produce computers" (M = 3.31, SD = 1.199) and lastly "energy consumption levels of computers" (M = 3.28, SD = 1.207).

Table 4. Nature of Computers Knowledge Levels

Item		Computer Experience		Overall
		Low	High	
"Environmental effect of computers"	M	3.08	3.56	3.34
	SD	1.296	1.209	1.199
"Energy consumption levels of computers"	M	3.08	3.46	3.28
	SD	1.280	1.114	1.207
"Poisonous chemicals used to produce computers"	M	3.11	3.47	3.31
	SD	1.258	1.122	1.199
"Computer power saving features"	M	3.03	3.60	3.34
	SD	1.056	1.117	1.125
Overall	M	3.075	3.522	3.317
	SD	1.222	1.140	1.178

The supremacy of students with high computer experience over those with low experience was consistent for all items, i.e. "computer power saving features" (High experience: M = 3.60, Low experience: M = 3.03); "environmental effect of computers" (High experience: M = 3.56, Low experience: M = 3.08); "poisonous chemicals used to produce computers" (High experience: M = 3.47, Low experience: M = 3.11); and "energy consumption levels of computers" (High experience: M = 3.46, Low experience: M = 3.08).

C. Influence of Computer Experience

1) Vocabulary: H1: Computer experience influences perceived knowledge of green computing vocabulary.

Table 5. Computer Experience and Vocabulary t-test Results

Experience	n	*df*	M	Mean diff	SD	*t*	Sig.
High	243	450	1.292	.145	.522	3.508	.000
Low	209		1.147		.350		

Results from the independent samples t-test in Table 5 reveal that students with high computer experience (M = 1.292, SD = .522) were more knowledgeable about vocabularies than students with low experience (M = 1.147, SD = .350). The difference in the group means of .145 was statistically significant, t(450) = 3.508, p < .001, representing an effect size of Cohen's d = .32 which is considered medium and hence rejecting the null hypothesis.

2) E-waste Management: H2: Computer experience influences perceived knowledge of e-waste management.

Table 6. Computer Experience and E-waste Management t-test Results

Experience	n	*df*	M	Mean diff	SD	*t*	Sig.
High	243	450	2.049	.853	.836	1.107	.269
Low	209		1.964		.792		

The independent samples t-test results in Table 6 show that both low and high experience respondents had almost similar levels of e-waste management knowledge. A small mean difference of .853 that existed between highly experienced students (M = 2.049, SD = .836) and students with low computer experience (*M* = 1.964, SD = .792) was not statistically significant, *t*(450) = 1.107, *p* = .269, *d* = .10, hence retaining the null hypothesis.

3) *Nature of Computers:* H3: Computer experience influences perceived knowledge of the nature of computers.

Table 7. Computer Experience and Nature of Computers t-test Results

Experience	n	*df*	M	Mean diff	SD	*t*	Sig.
High	243	450	3.521	.446	.842	5.536	.000
Low	209		3.075		.868		

From Table 7 of independent samples *t*-test results, students with high computer experience (*M* = 3.521, SD = .842) were more knowledgeable about the nature of computers than students with low experience (*M* = 3.075, SD = .868). The difference in the group means of .446 was statistically significant, *t*(450) = 5.536, *p* < .001, *d* = .52. The effect size was above the threshold for large effects and, hence, the null hypothesis was rejected.

D. Discussion

The low levels of green computing perceived knowledge among university students in this study are very consistent with findings from previous studies conducted around the world [17], [23], [24]. Given the general behavior of university students, it is imperative that their awareness about environmentally sustainable computing practices is increased. University students often possess multiple computing devices such as laptops, desktops, tablets, smartphones and printers, which they sometimes use simultaneously. With such high levels of usage coupled with the low levels of green computing knowledge especially concerning energy consumption of computing devices, universities will always face the challenge of high energy bills, thus, becoming major sources of carbon emissions. Unlike in developed countries, access to ICTs in low-income economies like Uganda is still very low. A few pupils get a chance to have access to computers and learn the basics of ICT during their pre-university education. This explains the low levels of computer experience in years among university students, especially those who participated in the study.

With that background in mind, and the assertion that one's level of computer experience has an impact on their literacy level about computer-related aspects [8], the substantial influence of computer experience on green computing knowledge levels among university students in Uganda can be justified. While students (regardless of their area of study) interact with computers, their perceptions about general ICT concepts change as they keep learning from their experiences. Therefore, if access to ICTs can be provided to all students, we can expect improved awareness among them about green computing concepts. This would enable them become more environmentally conscious while using computing devices.

The finding indicates that students across all levels of experience are not well informed about e-waste management activities. This can be attributed to the absence of proper e-waste handling routines at the university regarding disposal of defunct computing hardware like printers, computers, networking equipment and power supply units. Not even at national level has e-waste management been formally embraced as only a few companies are reported to be engaged in formal refurbishment and recycling of used computing hardware [4]. Majority of the few existing e-waste management undertakings are informal, operating as refurbishment workshops.

With such an operational ground, it can be justified that students' levels of knowledge about e-waste management are low regardless of their levels of experience, as a result of their day-today experiences both at university campus and outside. It is suggested that a person's direct experiences with a phenomenon has a much more impact on their behaviour [18]. It is also posited that perceived knowledge is partly

as a result of one's direct experiences [17], [25]. Thus, students' low levels of e-waste management knowledge across both levels of computer experience can be attributed to the unsatisfactory e-waste handling initiatives in the country and at the university in particular.

The findings have revealed an important fact that computer experience has an influence on green computing knowledge. It is recommended that future studies explore more about other determinants of computer experience other than the number of years, and relate them to green computing knowledge and eco-friendly behaviour. Furthermore, universities are encouraged to establish environmentally sustainable computing initiatives at their campuses. For instance, efforts towards proper e-waste disposal, energy-efficient practices and environmentally sustainable procurement. Relevant authorities are urged to help poor students at all educational levels have access to affordable computers in order to improve their general and sustainable computing skills and knowledge. Finally, the government of Uganda is urged to borrow a leaf from on-going sustainable initiatives in other parts of the world in order to reduce the country's carbon emissions and also improve public health.

V. Conclusion

The study has highlighted the state of awareness about sustainable computing among university students in Uganda. Students need ICT education and access to improve their environmental awareness and practice. Much as past research works on green computing awareness and knowledge have drawn comparisons between gender and field of study with varying results from different contexts, the study has opened up further investigation into computer experience as one of the most important factors affecting green computing knowledge among students. Future studies can make use of this observation and further expand it to suit different contexts and research objectives.

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