Knowledge of Green Computing among University Students and Lecturers in a Malaysian Public University

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Abstract: **This study examined the levels of green computing knowledge between students and lecturers, and between ICT and non-ICT respondents in a public university in Malaysia. Two types of green computing knowledge were assessed, perceived knowledge and objective knowledge. Perceived knowledge was assessed through respondents' self-rating of how much they knew about green computing on eight Likert items, and objective knowledge through seventeen True-False items. The sample consisted of 240 respondents, comprising 180 students and 60 lecturers, drawn using a purposive, random sampling. Data were collected using a self-developed green computing questionnaire, which was administered by hand and via e-mail. Descriptive statistics and independent-samples t-tests were used to analyze the data. Results show that almost half of the sample reported having completely no knowledge of green computing (49.5%), while 14.6% reported having a low level of knowledge. Those reporting having high (2.6%) and quite high (9.7%) levels were few in number. Results of the t-tests point to a no-significance difference between students and lecturers, but a statistically significant difference between ICT and non-ICT respondents. The findings suggest the importance of conscious training in energy-efficient computing to raise students' and lecturers' levels of knowledge in this very important area.**

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Keywords: ***Green computing, energy-efficient computing, eco-friendly computing, carbon-free computing***

I. INTRODUCTION

THE computer today is one of the most widely used machines ever invented. Its usage requires substantial amounts of electricity whether to power the system unit and monitor, recharge batteries, or print. A single computer consumes between 95 and 650 watts of electricity daily depending on its use, and releases much energy into the

environment, which accumulates to affect global temperatures. What is unknown to many is that computers and their by-products are manufactured using toxic chemicals, such as chromium, lead and mercury, which may likely become dangerous both to the user and the environment if inappropriately disposed of. Because of the negative consequences they may cause, computing activities need to be well-informed and well-regulated, particularly with respect to energy consumption. This process of checking the environmental effects of computing and the energy consumption resulting from computing processes is referred to as *green computing* [1].

Specifically, green computing covers a broad domain dealing with the study and practice of using computing resources efficiently, the consideration of the total cost of disposal and recycling of old hardware, and environmentally friendly treatment of the e-waste generated from computing resources [2]. Also lies within its domain is the study of effective ways of designing, manufacturing, using and disposing of computers, and its associated subsystems, such as monitors, printers, storage devices, and networking and communication system with minimal or no impact to the environment [3]. The primary objective of green computing is to promote a technology and usage pattern that is energy-efficient and environmentally friendly with less or no hazardous materials used or produced. It also promotes recyclability of used computer products and reduction of e-waste.

The practices of green computing involve reducing the electricity consumed and the environmental waste generated when using a computer and other electrical and electronic appliances. Green computing is seen as a way to achieve economic viability and improving system performance and usage against the backdrop of societal norms and ethical responsibilities toward the environment [4]. It is desirable that the society we live in be environmentally conscious by reducing electricity consumption and environmental waste resulting from huge uses of computers and other electronic devices. The practice of green computing is an interesting aspect that contributes towards improving energy efficiency and reducing waste in the life cycle of computing equipment. This includes the energy consumed to create computing equipment, get the equipment to a consumer, use and maintain

it, and discard or recycle the equipment at the end of its life cycle [5].

Existing literature on going green shows the business sector and industries increasingly moving towards adopting green policies and practices. Companies in the computing industry, particularly, have come to realize the urgency for going green, affirming that it is now in their best interest both in terms of public relations and cost reduction. Environmental organizations and other sectors of human activities too are beginning to realize the necessity for protecting the environment and energy saving along with computing operational expenses.

Many universities are also gearing up toward green initiatives – from green buildings and solar power to various student initiatives through awareness campaigns to comprehensive plans to go "carbon neutral." In the U.S., more than 500 universities and colleges have signed the American College and University Presidents (ACUP) Climate Commitment, which requires them to implement tangible plans in waste minimization, recycling, and energy use reduction. Signatory schools also pledge that they will integrate sustainability into their curricula, making it part of the educational experience for the entire campus population [6].

Students and lecturers make up a huge portion of a campus population, and are large users of computing resources and energy. Together these two groups produce large amounts of carbon emission daily, which in turn contribute substantially to global warming. Increased global warming resulting from computing activities is not likely to stop unless the people directly involved in the activities become responsible and conscious users of energy. In light of the fact that ICT infrastructure and computing power will continue to expand in capacity and reach, users of these resources must be sufficiently educated and well-informed about, or at least be made aware of the notion of energy-efficient computing.

II. LITERATURE REVIEW

Knowledge and awareness is the understanding of all facts that someone knows about a particular subject, issue, or ability to perceive or to be conscious of events, objects or situation [7]. Therefore, in relation to green computing, knowledge is the understanding of all the facts that someone should know about energy-efficient use of the computer so that the environment is not adversely affected by the computing activities. Most computer users are not knowledgeable about the amount of electricity that computers consume daily. This explains why most users wouldn't mind leaving their PCs on when not in use. It is quite common to find computers in offices, libraries, laboratories, student hostels, and staff rooms left perpetually on even after working hours are over. These occurrences are a clear indication that computer users and management personnel are not aware of

the amount of electricity they consume and the amount of carbon dioxide they emit into the atmosphere. According to a research conducted by Schneider Electric, an average desktop computer requires 85 watts just to stay idle, even with its monitor turned off. If that computer is logged off when not in use, over USD $40 in energy costs would be saved annually [8]. Now multiply that amount with a million PCs that are left idle everyday by users all over the world, and you would get a staggering amount of how much money and energy could be saved yearly.

The same study also further reported that one computer left for 24 hours a day consumes between USD $115 and USD $160 electricity annually, and will dump about 1,500 pounds of carbon dioxide into the atmosphere. If a tree absorbs between 3 to 5 pounds of carbon dioxide each year, up to 500 trees are needed to offset the annual emission of one computer that is left on all the time. This means that to offset the amount of carbon dioxide emitted by the computers in a typical Malaysian university library alone, over one billion trees are required, even when such computers are left in a hibernate or sleep mode. The average university student or lecturer, unfortunately, is not aware of this fact and the magnitude of the situation. In fact, in a study assessing the levels of Botswanan university students' knowledge of green computing, it was discovered that a huge majority were ignorant about green ICT issues, displaying either extremely limited or no knowledge whatsoever in the subject matter [9]. Similarly, it was found that university students in Mauritius generally lack a thorough understanding of green computing and practices that are compliant with the notion [10]. If left unaddressed, this lack of knowledge will likely encourage continued energy wastage among university populations.

It was estimated that USD $250 billion per year is spent on powering computers worldwide, and only about 15% of that power is spent on real computing [11]. The rest is wasted idling. A huge number of users worldwide leave their computers unattended to during working hours and throughout the day, or they leave them on over the weekend. If all this wasted energy is saved on computing and computer hardware, it will prevent tonnes of carbon emissions into the atmosphere every year. Collectively computers consume a tremendous amount of electricity, but much of this energy went into unnecessary and wasteful usage. This pattern of wastage and wasteful computing will likely escalade, considering that information technology is increasingly becoming popular in use. Hence there is an urgent need to go green with everybody, especially university students and lecturers, mobilized to contribute so that energy consumption and carbon emission resulting from computer use can be controlled and regulated in order to save the environment.

PC users generally have three choices before walking away from their computers. They can choose to standby, hibernate or shutdown, but the simplest and best choice is to shut it down, as this option saves the most power and is good for the computer and the environment [12]. Shutting down a PC when it's not in use is a good practice compliant with green

computing. Other alternatives, like the standby or sleep mode, still keep the computer running and documents open, and power is used up unnecessarily to feed to the memory. A full shut down powers off the computer completely, and is always the best option when the computer is not in use. It is the best eco-friendly option because it draws no power, and power saving means financial savings. In the U.S. alone, organizations waste USD $2.8 billion and 20 tons of carbon dioxide each year powering idle computers, which can be saved if these computers were simply shut down [13]. The awareness of these facts must be raised in all parts of the world, especially among university populations, to reduce this extreme wastage.

It is also necessary to go green looking at the rate of electricity consumption of computer monitors. A typical computer uses an average of 60 to 500 watts, and with an LCD or a CRT monitor, a computer will use an additional 35 to 150 watts of electricity, thereby making the total electricity consumption by a single computer about 95 to 650 watts [14]. Moreover the question of what to do with old computer hardware, especially CRT monitors, is an important consideration due to the toxic nature of their makeup. The leaded glass portion of the cathode ray tube contains significant quantities of lead which is toxic, and may explode when deposited in a landfill and react with other dangerous chemical elements. This chemical interaction can contaminate the air, the soil and ground water, and the resulting effects are hazardous to all kinds of life within the environment. All these problems can be avoided by simply going green. University students and lecturers who are conscious of green computing facts such as these are more likely to do the necessary to cut down on the energy consumption, deal with e-waste appropriately and go green.

III. STATEMENT OF THE PROBLEM

Despite the enormous importance of green computing understanding and knowledge for university populations, extremely few studies have been done to address this issue within the university context. University lecturers and students are perpetual users of computers, and their usage patterns affect global consumption of electricity and the resulting energy and carbon emissions produced. Yet only two studies could be located that addressed green computing knowledge of university students – those of Batlegang (2012) and Dookhitram, et.al. (2012). More attention should be given to studying what university students and lecturers know about energy-efficient computing as the information drawn from such studies can be used to draw up green initiatives on university campuses.

IV. PURPOSE OF THE STUDY

The purpose of this study, therefore, was to examine the levels of green computing knowledge among students and lecturers on a number of issues related to computing and its effects on health and the environment. Two types of knowledge was assessed in this study, namely *perceived knowledge* based on respondents' self-rating of several green issues, and *objective knowledge* deducted from respondents' performance on a set of True-False items.

The study also set out to determine if statistically significant differences existed in the levels of green ICT knowledge between students and lecturers, and between ICT and non-ICT respondents. The latter comparison was made with the purpose of establishing the role of specific ICT education or training in raising the level of green computing knowledge among university populations.

V. RESEARCH QUESTIONS

The study was designed to answer the following questions in relation to students' and lecturers' perceived and objective knowledge of green computing:

1. What is the perceived level of green computing knowledge of the university students and lecturers surveyed in the study?
2. Is there a statistically significant difference in the levels of objective green computing knowledge shown by the university students and lecturers?
3. Is there a statistically significant difference in the levels of objective green computing knowledge shown by ICT and non-ICT respondents?

VI. METHODOLOGY

The study was a cross-sectional survey designed to identify the levels of respondents' perceived and objective knowledge of green computing, and to compare these levels between the student group and the lecturer group, as well as between ICT and non-ICT respondents.

A. Data Collection and Sample

The sample consisted of 180 students and 60 lecturers from a Malaysian public university, making a total sample of 240 altogether. Half of the respondents (50%) were from ICT-related fields, while the other half from various non-ICT specializations. They were selected from the public university's six faculties using a combination of random and purposive sampling technique. The questionnaires were administered by hand and via e-mail. The researchers used a number of follow-up measures, i.e. email reminders and phone calls, to ensure a high response rate. Out of the 400 sent out, 240 usable questionnaires were returned, constituting a response rate of 60%.

B. Instrument

Data were collected using a self-developed questionnaire that contained eight (8) perceived knowledge items and seventeen (17) objective knowledge items. The perceived knowledge items asked the respondents to rate, on a 5-point Likert scale *(High, Quite High, Moderate, Low,* and *None),* the degree of their knowledge on eight green computing aspects. The objective knowledge items were True-False

questions. After being generated, the items were subjected to validation by ICT and psychometric experts, and later pilot tested on a representative sample of the target respondents. The reliability of the data generated from the items was found to be high, i.e. $\alpha = 0.92$ for perceived green computing knowledge and $\alpha = 0.89$ for objective knowledge. Both indices constitute very good indicators of reliability for a study [15, 16].

C. Data Analysis

To address research question 1, responses to the eight Likert items on perceived green computing knowledge were collapsed and the mean percentage for each response category, i.e. *High, Quite High, Moderate, Low,* and *None,* was computed. To address research questions 2 and 3, responses to the seventeen True-False items were graded and given a score, i.e. 1 for correct response and 0 for wrong and I-don't-know responses. The scores were then summated, yielding a group score each for lecturers, students, ICT respondents and non-ICT respondents. Two independent-samples *t*-tests were performed on the group scores to see if statistically significant differences existed between the groups with respect to the levels of objective green computing knowledge. The level of statistical significance adopted for the analysis was $p \leq 0.05$, which formed the basis of whether a significant difference existed between the groups or not.

VII. RESULTS

The first research question asked was, *"What is the perceived level of green computing knowledge of the university students and lecturers surveyed in the study?"* A percentage analysis of the eight Likert items on the perceived levels of green computing knowledge (Fig. 1) shows that a majority (64.1%) of the respondents have either very low or no knowledge of green computing at all, while the remaining 35.9% of the respondents have between moderate and high levels of knowledge about green computing. About half the sample had completely no knowledge of green computing. Those who perceived having quite high and high levels of knowledge constitute only 12.3%.
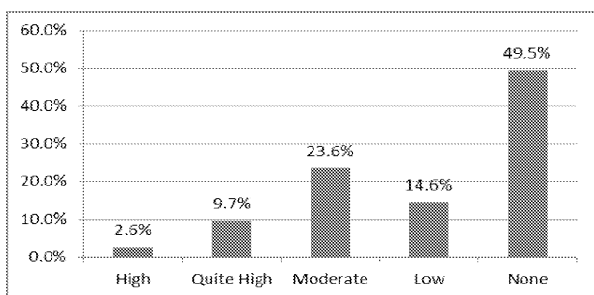

Fig. 1. Perceived Levels of Green Computing Knowledge among Respondents *(Percent)*

Research question 2 reads, *"Is there a statistically significant difference in the levels of objective green computing knowledge shown by the university students and*

lecturers?" To address this question, an independent-samples *t*-test was performed on the group scores of students and lecturers. The results are presented in Table 1.

TABLE I
T-TEST RESULTS OF STUDENTS' AND LECTURERS' OBJECTIVE KNOWLEDGE OF GREEN COMPUTING

Respondents	n	df	M	SD	t	p-value
Lecturers	58	234	8.50	4.301	.856	0.393*
Students	178		7.98	3.947		

*not significant at $p < 0.05$

The results point to a no-significance difference between the group scores of students and lecturers. Although lecturers yielded a higher mean score (M=8.50, SD=4.301) than students, this difference was not statistically significant. It can be concluded that both groups are about equal in terms of factual knowledge of green computing ($t = 0.856$, df = 234, $p = 0.393$).

Table 2 presents the *t*-test results between ICT and non-ICT groups. The statistics show ICT respondents performing better on the True-False items, yielding a mean score of 3.13 points higher than that of non-ICT respondents.

TABLE 2
T-TEST RESULTS OF ICT AND NON-ICT RESPONDENTS' OBJECTIVE KNOWLEDGE OF GREEN COMPUTING

Respondents	n	df	M	SD	t	p-value
ICT	119	234	9.66	3.692	6.444	0.001*
Non-ICT	117		6.53	3.759		

*significant at $p < 0.05$

The results indicate a statistically significant difference between the ICT and non-ICT groups, with the ICT respondents showing a significantly higher mean score in objective green computing knowledge (M = 9.66, SD = 3.692) than the non-ICT respondents (M = 6.53, SD = 3.759). This shows that these two groups are not equal in what they know to be the facts of green computing ($t = 6.444$, df = 234, $p = 0.001$). These results address research question 3 which states, *"Is there a statistically significant difference in the levels of objective green computing knowledge shown by ICT and non-ICT respondents?"*

VIII. DISCUSSION

Several key findings emerge from the study. First, Malaysian students and lecturers generally have either low levels of green computing knowledge or none at all. Very close to half reported having zero knowledge about this subject matter. The pattern implies a likelihood of finding more Malaysian students and lecturers who *would not know* about green computing and eco-friendly computing facts than finding those who would. Second, lecturers and students do not appear to differ significantly in their knowledge of eco-

friendly and energy-efficient computing. This finding was thought to be rather surprising as it was generally assumed or expected that lecturers, being the custodian of knowledge in the university, would have significantly higher levels of knowledge in anything than would students who are the receivers of knowledge. What this suggests for both groups is that being in higher education and being computer literate do not necessarily equip one with knowledge of green computing. That knowledge has to be consciously taught or acquired via conscious reading. Third, ICT students and lecturers are superior to their non-ICT counterparts in terms of green computing knowledge, which is expected because they would have acquired this knowledge through their ICT-related courses. These courses would have laid the foundation for and raised awareness about energy-efficient computing. This supports the earlier claim that knowledge of what green computing constitutes must be consciously taught or acquired.

The finding on university students having low levels of green computing knowledge is consistent with that of Batlegang (2012) and Dookhitram, et.al. (2012). Both studies found a similar lack of knowledge among Bostwanan and Mauritian university students. Not just students, but most individuals are generally ignorant about the energy loss and environmental issues associated with the daily use of computers, unless they come into meaningful contact with these issues either formally or informally. Much more energy loss and wastage is expected if this state of ignorance persists. Among Malaysians, some consciousness does exist on the need to go green, as is the case in most Asian societies, but it has not translated into actual green initiatives and efforts to increase the stock of green knowledge [17].

IX. CONCLUSION

The study has shed light on the levels of green computing knowledge possessed by university students and lecturers, the two largest ICT user groups within a university setting. The scenario that emerged from the findings is less than desirable. Given the importance of green computing awareness and knowledge, universities and government agencies should take the first step in educating campus populations, as well as the public, regarding the *"what"* and the *"how"* of green computing. Raising their awareness levels in how to go green particularly should be an important agenda for the university and the government. Hence, more studies of this nature that delve into knowledge and awareness levels of diverse university populations are much needed to provide baseline data for green initiatives in Malaysian universities. Studies looking at actual computing practices of students will also generate insightful data into the state of environmentally friendly computing that exists on university campuses.

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