

# The Cognizance of Green Computing Concept and Practices among Secondary School Students: A Preliminary Study

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**Abstract**—The use of information communication technology (ICT) is growing and has been a compulsory norm in society. However, the increased use of ICT facilities in all developing countries has contributed to higher energy use and lead to environmental pollution. This study explores the extent of awareness among the younger generation about green computing concepts and practices. In this study, a total of 94 secondary school students were sampled across Selangor state. The data were gathered using a set of questionnaires comprising of 20 items pertaining to the harmful effects of using computers and communication gadgets on the environment, awareness of the concepts and practices of green computing. The findings indicate it reveal that secondary school students are still not aware of the green computing concept. It is observed that 54.35% of students may not realize that computers and communication devices could be disposed of eco-safe. Furthermore, 61.96% of students do not realize that computer hardware can be recycled, and 75% of them do not have experience in disposing of their computers. Surprisingly, they mostly practice green computing when it comes to reducing energy consumption. This study contributes to determining the current level of students' green computing awareness in a sustaining environment. In conclusion, students need to be educated on utilizing ICT resources and practicing green computing mechanisms to boost environmental sustainability.

**Keywords**—Awareness; energy consumption; green computing; environment pollution; secondary students

## I. INTRODUCTION

The utilization of electronic devices, including computers, brings great benefits to human beings. Conversely, this

utilization has led to a rise in energy consumption, electronic waste, as well as to adverse impacts on human health and the environment [1,2]. For example, e-waste generation has been recorded globally, with a volume of 4.18 million metric tonnes in 2014, and e-waste generation exposure human to toxic elements [2,3].

Therefore, the initiatives to foster green computing and energy minimization include low carbon emissions and efficient use of resources, have been highlighted [3, 4]. Green computing is defined as energy-efficient computing practices, eco-friendly, responsible use of computers, and other resources in sustaining environment [5, 6]. Green computing has four major components known as (1) manufacturing and production of computer resources, (2) design of computer system and system resources, (3) usage of computer resource management, and (4) disposal of computer resources and e-waste [7, 8].

The practice of green computing able to reduce energy usage, lower carbon dioxide emissions, conserving resources where less energy is required to produce, use and dispose of products, saving energy and resources, and reducing the risk that might cause health problems and environmental pollution [9]. Green computing encourages recyclability and biodegradability, uses network and computing in proper ways includes promote paperless policies and reduce print volumes, adopting conference calls, use blank screensavers option, and hibernating [6,10].

Then again, green computing requires participation and support from individuals, the community, government, and

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private sectors to ensure this effort to sustain a healthy environment. The adoption of green computing practices in sustaining the environment is dependent on green computing awareness and behavior [1,11]. Moreover, the knowledge related to green computing is recommended to be introduced from an early age [12].

Further, the awareness studies on green computing in most countries are conducted for higher institutions. This is due to the massive use of ICT such as digital databases, laptops, LCD, and distance learning programs, and students in the higher institutions are considered a huge segment of ICT users [4, 13]. However, far too little attention has been paid to the awareness of green computing among younger generations, especially among school students.

Besides that, the industrial revolution 4.0 changes the landscape of education, where the concept of Education 4.0 was introduced. Education 4.0 requires primary, secondary, and higher institution students to be digital literate. Therefore, teaching and learning can be conducted in various ways, such as using collaborative software and apps, conducting classes through Google Classroom, using virtual and augmented realities for education [5]. Due to these matters, the research aims at exploring (i) awareness on the impact of using ICT towards environments, (ii) identifying awareness on green computing concepts, and (iii) exploring the green computing practices among secondary school students in urban areas.

Therefore, Section II explained the research background, including the ICT and environment, green computing and its initiative, and the awareness and practices in green computing. Then, the method used in this study is elaborated in Section III and the results are presented in Section IV. Finally, the discussion, concluding remarks and some suggestions for future works are described in Section V.

## II. LITERATURE REVIEW

### A. ICT and Environment

Since the 1990s, researchers have made a significant contribution to the environmental consequences of ICT. The relationship between ICT and the environment is complex stated in several studies, as ICT leads to positive and negative environmental impacts [14-16,18]. The study of [17] addresses the global consumption of residential electricity by ICT equipment, which increased by almost 7 percent (7%) per year between 1990 and 2008. Even with expected improvements in energy efficiency, electronics consumption is expected to increase by 250% by 2030. Further support is given by [15], which more specifically asserts that ICT decreases CO<sub>2</sub> emissions from developed and developing countries over the period 1990 to 2017 for a complete sample of 91 countries.

Besides, a finding published in [18] stated that ICT influences the environment via three channels, which are:

- **Usage effect** during production, refining, distribution and installation of ICT equipment contribute significantly to CO<sub>2</sub> emissions.

- **Substitution effect** is described as the reorganization of the production process, including decarbonization of dematerialization, demobilization, replacement of physical products with e-books, e-mail and teleconferencing postal mail, smart transport system, GPS, smart camera traffic control system, and reduction of outdoor activities.
- **Cost effect** in which ICT raises the demand for other goods and services due to a drop in prices and a rise in the return of CO<sub>2</sub> pollution.

However, comparative studies have shown that using ICT in developed countries promotes environmental sustainability. It implies that it would be possible to contribute to environmental sustainability and ICT diffusion with greater levels of development of the country. [15,18].

### B. Green Computing and its Initiative

The initiative of green computing [19]:

1) *Virtualization*: Virtualization is one such form of technology that provides access from a remote location to servers or users. Nowadays, the green initiative has progressed into the idea of virtualization, in which cloud computing plays an important role.

2) *Power management*: The need for power management in any computer system is highly insisted because of the prolonged battery life, reduction in the cooling requirements, noise also. The hibernate option available in the system is one such kind of power management technique supported comprehensively and efficiently as it will automatically switch off the RAM and CPU of the system, reducing the amount of background working of the system.

3) *Power supply*: Power supplies are also one such factor that will help achieve the green computing concept by implementing the green systems. The drain of more power is supportive in designing a system in an efficient manner. The idea of purchasing and using the power suppliers with “80 plus” certification is considered the best way to save power in the system (State Legislation on E-Waste, 2008). The use of this sort of useful and efficient power supply can probably reduce the wastage of energy consumed and the heat generated in the system.

4) *Displays*: The displays emit heat directly into the device, thereby consuming more fuel. Therefore, the principle of replacing LCD monitors and LED displays with light-emitting diodes are. It's called the best idea. It's because the fluorescence is due to the lamp used consumes more energy and emits elevated heat. Research shows that the LCDs are 66 percent more energy efficient and are also 80 percent highly skilled in growing the system's size and weight. In contrast, the CRT uses about 120W of power, which is twice the power used by the 22-inch LCD. Therefore, any person needs to look for the device components before buying, including the displays, which will probably help reduce the power consumed.

5) *Video cards*: The reduction in the use of video card is considered to be a wise idea as it cannot use the shared terminal, think client or cannot even have desktop sharing properties, which are highly helpful in saving the energy consumed in the system. The reuse of older video cards is considered a wise idea as it will consume only lesser power, thus reducing the heat sinks or fans. The selection of GPU with average wattage or performance per watt is also considered to be a much wiser in the idea of selecting the green system implementation.

### C. Awareness and Practices of Green Computing

Theoretically, a "green concept" containing elements of ZEB (Zero Energy Building) and 3R (Reuse, Minimize, Recycle). Green technology's principles include: sustainable, the use of reclaimed natural resources, the manufacture of material that can be reused, the utilization of waste products and chemicals that can be recycled, creative and not adverse to health and environment, the production of practices and products that are environmentally friendly and can protect the earth [20, 22,23]. Green Computing also can be interpreted as "the practices and procedures of using computing resources in a friendly environment way while maintaining overall computing performances" [21]. It has also been stated that green awareness can be divided widely into five community groups [22]:

- 1) Hardware Manufacturer.
- 2) Corporate and Public Consumers.
- 3) Individual Consumers.
- 4) Enforcement Authority.
- 5) Software Designer & Developers.

The most critical aspect of green computing when it comes to practise is the users' attitude towards it and their perceived green computing behavior over green computing's actual behavior. Currently, the major challenge restricting green technology is because the concept itself has not been well socialized to the community. Communication networks are therefore required to promote the adoption of green technology among the general public through communication technology and other communication activities, since the characteristics of network technology and communication affect the implementation of green technology. Communication efforts are also required to spread the value of green technology's position to raise public awareness of environmental issues [20-22].

### III. METHODOLOGY

A set of questionnaires was used in this study. The questionnaire is divided into two sections. Section A consists of items related to demographic information. Meanwhile, Section B contained 20 items associated with the impact of using ICT on the environment and the knowledge and practices related to green computing. This section was designed using a dichotomous response scale.

The data were collected using purposive and convenience sampling method. These sampling methods considered the age of respondents ranging from 13 until 17 years old and

conveniently participating in this study. There were 100 questionnaires distributed to secondary school students around Selangor, and 94 questionnaires were returned. Respondents from Selangor are selected as the sampling site because Selangor has the highest enrollment of secondary students in Malaysia with a total number of 364 442 students [24].

However, 92 questionnaires are valid for further analysis. A descriptive analysis was used to analyze the data using Microsoft Excel. The findings of the study are based on the response received through the filled-in questionnaire. This study adapting percentage interpretation from [25] to interpret the level of awareness (Table I).

TABLE I. THE INTERPRETATION FOR AWARENESS LEVEL ON GREEN COMPUTING

| Percentage of students' awareness (100%) | The level of awareness of green computing |
|--|---|
| 75-100                                   | High                                      |
| 50-74                                    | Average                                   |
| 25-49                                    | Low                                       |
| 0-24                                     | Very low                                  |

### IV. RESULT

This section explains the results gain from the survey.

#### A. Demographic Profile

Table II shows the result of a demographic profile based on gender and age. The demographic distribution shows that 61.0% of respondents were female, and 39.0% of respondents were male who participated in this study. The majority of respondents involved in the study were 16 years old (64.0%), followed by 17 years old (31.0%) and 15 years old (2.0%).

#### B. Awareness of the Harmful Impact of ICT uses towards Environment

Fig. 1 shows the findings gain on their knowledge and awareness of the harmful impact of ICT Uses on the environment. Question 1 (Q1) aims to know whether secondary school students in Malaysia concern about the environment. This study reveals that 91 (98.91%) respondents agreed that they are concern with the environment. Question 2 (Q2) shows that most respondents (54.35%) did not know that the use of computer hardware can contribute to a harmful impact on environments. Question 3 (Q3) indicates that the majority of respondents (89.13%) know about carbon admission (CO<sub>2</sub>). Despite that, findings obtained for question 4 (Q4) show that 55 (59.78%) respondents did not know that computers and IT gadgets can produce carbon emissions. Question 5 (Q5) addressed that electricity usage can contribute to environmental pollution, and 65 (70.65%) respondents agreed with this question. Based on the findings obtained for Question 6 (Q6), 30 (32.61%) respondents know that most of the computer and its gadgets are not biodegradable. Overall, the average knowledge on the impact of ICT use on the environment is only 61.96% and this indicates that the awareness on the impact of ICT uses towards the environment is at the average level.

TABLE II. DEMOGRAPHIC PROFILE OF RESPONDENTS (N=92)

| Item   | Description  | Frequency | Percentage (%) |
|--------|--------------|-----------|----------------|
| Gender | Female       | 56        | 61             |
|        | Male         | 36        | 39             |
| Age    | 17 years old | 31        | 34             |
|        | 16 years old | 59        | 64             |
|        | 15 years old | 2         | 2              |

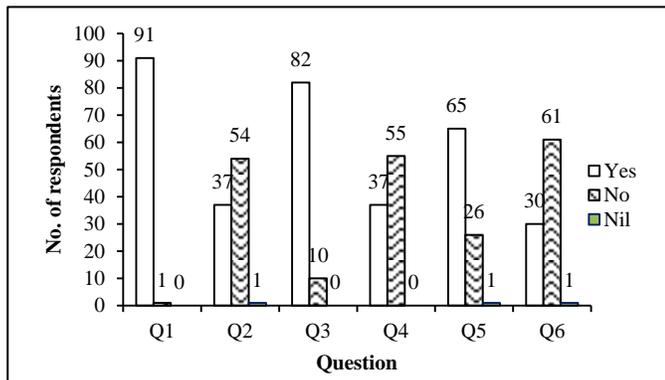


Fig. 1. The Awareness of the Harmful Impact of ICT on Environment.

Therefore, these findings show that students from different level of education remain to have less knowledge and awareness on the impact of ICT to environment [26]. Knowledge on the impact of ICT to environment is commonly being neglected to be exposed to students. Knowledge is a crucial part that should be considered as main priority in raise green computing awareness [7]. Educating students whether from schools and higher education, is vital to encourage them to used ICT in proper techniques while considering the negative impacts on the environment. For example, students are encouraged to use power-saving techniques that present in their computers or other devices. These techniques can reduce electricity consumption and indirectly reduce carbon footprints and other environmental effects [27].

C. Awareness of the Concept of Green Computing

Fig. 2 shows the respondents' awareness of the concept of green computing. Question 7 (Q7) was addressed to know whether the secondary school students aware of any campaign on green computing, question 8 (Q8) was proposed to know the awareness on the definition of green computing and question 9 (Q9) was proposed to identify the awareness on the green computing mission. The findings show a total number of 33 (35.87%) respondents noticed any campaign related to green computing, 40 (43.48%) respondents know the definition of green computing and 53 (57.61%) respondents know that the mission of green computing is to reduce computer hazardous material and to sustain environmental health. The total average of respondents agreed with these three questions is only 45.65%. As a result, this survey showed that the level of students' awareness of green computing is at a low level.

Interestingly, these findings are consistent with a study conducted in 2013 for Malaysian undergraduates [13]. Even though the approach used in accessing the awareness of green

computing concepts is different, both findings show that secondary school students and undergraduate students have little knowledge of the concept of green computing. Therefore, campaigns promoting the concept of green computing such as e-waste or carbon-free computing should be conducted continuously. Furthermore, [13] suggested that future research should be focused on whether students will practice green computing and their intention to embrace the idea.

D. Awareness of the Green Computing Practices

Eleven questions were delivered to identify secondary school students' awareness of green computing practices (Table III). Question 10 until 15 (Q10-15) aims at identifying the secondary school students' awareness of green practices related to recycling and disposing of computers and their gadgets. Based on Q10, it shows that the majority of the respondents (57.61 %) have more than one computer. Q11 shows that 54.35% respondents did not know that computers and their gadgets can be disposed; Q12 reveals that respondents did not know computer hardware can be recycled (61.96%) and Q13 shows 75% respondents do not have experience disposing of their computer hardware. Therefore, there are possibilities that respondents will not manage their e-waste properly. The higher numbers of ownerships for computers and devices means there will be more e-waste generated. Manufactures are recommended to produce computers and their devices are more durable and long lasting to reduce e-waste generation. Furthermore, secondary school students should be equipped with knowledge in discarding or recycling e-waste [2, 28].

Interestingly, Q14 shows that most respondents did not print more than 20 papers per day (82.61%) and Q15 shows that most respondents think that refilling printer cartridge is better (56.53%). According to [27], most printed papers end up as garbage in landfills. Further concern about the use of papers is related to the issues of deforestation where 93% of papers are produced from trees. Regarding the printer cartridge, users are suggested to use certain ink optimization techniques that able to reduce the amount of ink used to print pages. This method is expected to reduce the number of cartridges [27]. Based on findings obtained for Q14 and Q15, it can be concluded that secondary school students contribute less on the paper wastage and have a positive thought in recycling cartridge. Moreover, it is expected that they will continuously use less paper and refill their printer cartridge.

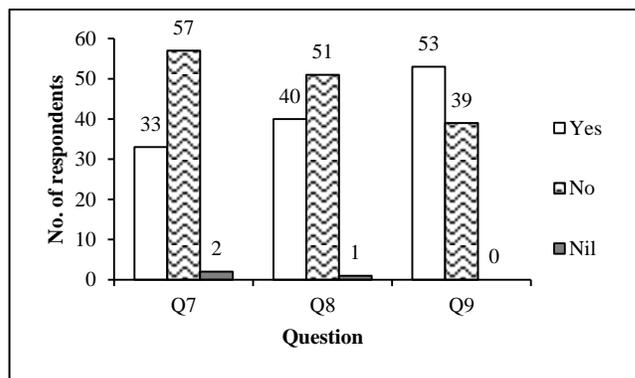


Fig. 2. The Awareness of the Concept of Green Computing.

TABLE III. THE AWARENESS OF GREEN COMPUTING PRACTICES (N=92)

| Practice                | No. | Question  | Yes            | No             | Nil          |
|-------------------------|-----|---|----------------|----------------|--------------|
| Recycling and Disposing | Q10 | Do you have more than one computer?   | 53<br>(57.61%) | 37<br>(40.22%) | 2<br>(2.17%) |
|                         | Q11 | Do you know that computer including its gadget (smartphone, tablet, etc.) can be disposed of? | 42<br>(45.65%) | 50<br>(54.35%) | 0<br>(0%)    |
|                         | Q12 | Do you know that computer hardware can be recycled?   | 35<br>(38.04%) | 57<br>(61.96%) | 0<br>(0%)    |
|                         | Q13 | Do you have any experience dispose of your computer hardware?                                 | 22<br>(23.91)  | 69<br>(75%)    | 1<br>(1.09%) |
|                         | Q14 | Do you print more than 20 pages per day?  | 16<br>(17.39%) | 76<br>(82.61%) | 0<br>(0%)    |
|                         | Q15 | Do you think that a refill printer cartridge is better than buying a new cartridge?           | 52<br>(56.52%) | 37<br>(40.22%) | 3<br>(3.26%) |
| Energy Consumption      | Q16 | Do you use a computer or its gadgets for a long duration?                                     | 41<br>(44.57%) | 50<br>(54.35%) | 1<br>(1.09%) |
|                         | Q17 | Do you use a computer for more than 5 hours per day?  | 25<br>(27.17%) | 67<br>(72.83%) | 0<br>(0%)    |
|                         | Q18 | Do you switch off your computer once you have done your work?                                 | 77<br>(83.70)  | 13<br>(14.13%) | 1<br>(1.09%) |
|                         | Q19 | Do you use a screensaver on your PC?  | 61<br>(66.30%) | 30<br>(32.61%) | 1<br>(1.09%) |
|                         | Q20 | Do you think that using a screensaver can save computer energy?                               | 64<br>(69.57%) | 27<br>(29.35%) | 1<br>(1.09%) |

On the other hand, question 16 until 20 (Q16-20) was delivered to assess the awareness of green computing practices in the context of energy usage. Question 16 shows that 50 respondents (54.35%) did not use a computer and its gadget in a long duration. The findings for question Q17 show that 67 respondents (72.83%) stated that they did not use the computer for more than 5 hours. In response to Q18, most respondents (83.7%) will switch off the computer once they complete their work. Based on these three questions, respondents are considered to have good practices in reducing energy consumption [4]. In contrast, 61 respondents (66.3%) use screensaver and 64 respondents (69.57%) agreed that screensaver could save energy. Findings related to the use of screensavers show that respondents did not aware that screensavers do not save energy [27].

## V. DISCUSSIONS, CONCLUSIONS AND FUTURE RESEARCH

The current study found that secondary school students feel concerned about the environment. However, they did not grasp the concept of green computing includes the meaning of the term 'green computing' itself. Although they know that the emission of carbon dioxide can increase in global temperature but they did not know that the computer and their gadgets are part of it. Most of them did not have experience in disposing of the old computer hardware. In general, therefore, it seems that they did not know that computers and their gadgets could be harmful to the environment. This result may be explained by the fact that they are not being exposed to e-waste management.

Nonetheless, they are prone to refill printer cartridge rather than buy a new one; this shows that, they were indirectly practising green computing although they have less understanding of it. Besides, they also printed less than 20 papers per day as this also helps in practising green computing. However, they also believe that by using a screensaver on a computer can reduce energy consumption. These findings suggest that they did not aware that screensavers do not save energy as their knowledge of green computing is low. Therefore, at this point, all the essential stakeholders in Malaysia include parents, teachers, governments and non-profit organisations must play a role to raise awareness of green computing among the younger generations, primarily through formal and informal education.

Several recommendations could be considered in educating and promoting green computing awareness to secondary school students. These followed recommendations are adapted from [6, 10]:

1) The government could establish a green computing master plan for secondary school students. This includes introducing the concept of green computing and practices as well as the advantages of implementing green computing.

2) Provides information green computing to teachers and school staffs.

3) Promotes the idea of recycling computer hardware and IT gadgets and preparing a framework for disposal e-waste in safety ways.

4) Encourage schools to use sustainable energy such as solar, wind and hydro. This example of energy usage will promote students to be more aware of alternative energy besides too dependent on electricity and the ability to reduce energy.

5) Use websites and social media to promote green computing.

6) Encourage schools to purchase and use most "greenest" computers.

7) Encourage and recognize programs for green computing. For example, video competition, posters, slogan or Green-day programs that might bring awareness to secondary school students.

In conclusion, this study gives a brief view of the current state of secondary school students' awareness of green computing. The study reveals that secondary school students'

have an average level of awareness of green computing. Therefore, secondary school students, especially the younger generations, should be informed about the concept of green computing, the practices, and benefits of green computing. Since this study involves a small number of respondents, future research should consider a broader range of respondents to develop an awareness amongst individuals and the community.

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