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Integrated Smart Home Model:
An IoT Learning-Inspired Platform

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ABSTRACT

Today, in the realm of Industry 4.0, vastly diverse internet of things (IoT) technologies are integrated everywhere, not to mention included in academic programs in schools and universities. Domain ratio of the final year projects in Universiti Teknologi MARA exposes a staggering hype in IoT as compared to other domains despite not having IoT included in any of the courses. Meanwhile, to fulfill the needs of the student in exploring this technology, an integrated IoT learning platform is developed. It integrates an IoT smart home model and a web-based interface as a learning platform to inspire hands-on learning for the students. The raspberry pi, motion sensor, analog gas sensor, atmospheric sensor, ultrasonic proximity sensor, and rain detector sensor are integrated together in a Lego-built smart home model where its connectivity and readings are displayed in a simple web interface to enable and inspire learning. A manual to set up the entire model is also prepared as a guide for students to set up and further explore the functionalities and operabilities of "things."

KEYWORDS

Analog Gas Sensor, Atmospheric Sensor, Internet of Things, Motion Sensor, Rain Detector Sensor, Raspberry Pi, Sensors, Ultrasonic Proximity Sensor, Web-Based System

INTRODUCTION

The Internet of Things (IoT) has been through and is still going through a technological revolution that enables ubiquitous interaction between objects or "things", people and the surroundings. Data are collected by embedded sensors and actuators, which are then sent to dedicated applications to be processed into information for further actions to be taken (Bagheri & Movahed, 2016). According to Gartner forecast, IoT will be embedded in 95% of devices in 2020 ("Gartner Predicts 2018 | Information Technology Predictions," n.d.). As real as the hype on IoT, it is definitely trending in many domains today such as military, agriculture, architectural development, healthcare, transportation and including education. It's a technology that not only is vast influencing how the millennial live but also how they study (He, Lo, Xie, & Lartigue, 2016; Koshy, Shah, Dhodi, & Desai, 2017). In line with this trending technology, the education sector should be at par in providing the facilities to equip the students especially to those study in the field of Information Technology (IT) (He et al., 2016; Raikar, Desai, & Naragund, 2017; Suduc, 2018).

UiTM has yet to have an Internet of Things (IoT) platform of its own, and students are not exposed to this trending technology. Students undertaking Data Communication and Networking and

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Netcentric Computing programs learn about the interconnection of an internet in TCP/IP, network design and network administration courses, though have inadequate knowledge about IoT since no specific theoretical or practical content are included in the programs' syllabus just yet. However, a survey of students' interest in the core domains of these two courses shows a trending, inclining interest in IoT related projects as compared to other domains such as computer networking, computer and network security, mobile-based applications, web-based systems and others, whereby a staggering 60% of students enrolled in these courses had chosen IoT based projects as their research or work domain in their final year project.

Adequate facilities and academic material and content are provided both physically and virtually though hardware and software for supporting the teaching of networking, however limited to only the traditional wired and wireless client-server setup and operation. For years before the era of IoT, students were only mastering the knowledge and skills of managing the for mentioned networks and not the knowledge of and skills of managing IoT networks. This includes the knowledge and practical skills of how microprocessors such as Arduino or Raspberry Pi platforms work in terms of its physical board and other hardware, the libraries and the integrated development environment (IDE), integration and communication with other sensors, software or applications. Students should also be provided with the knowledge on how to program these microprocessors via C or C++ code and how to access the pins on the board via the software to control external devices. This also includes integration with other systems, databases and the cloud for storage purposes. Apart from these possible integration or extension of the technology, IoT security is also an essential inclusion to the research field relating to IoT.

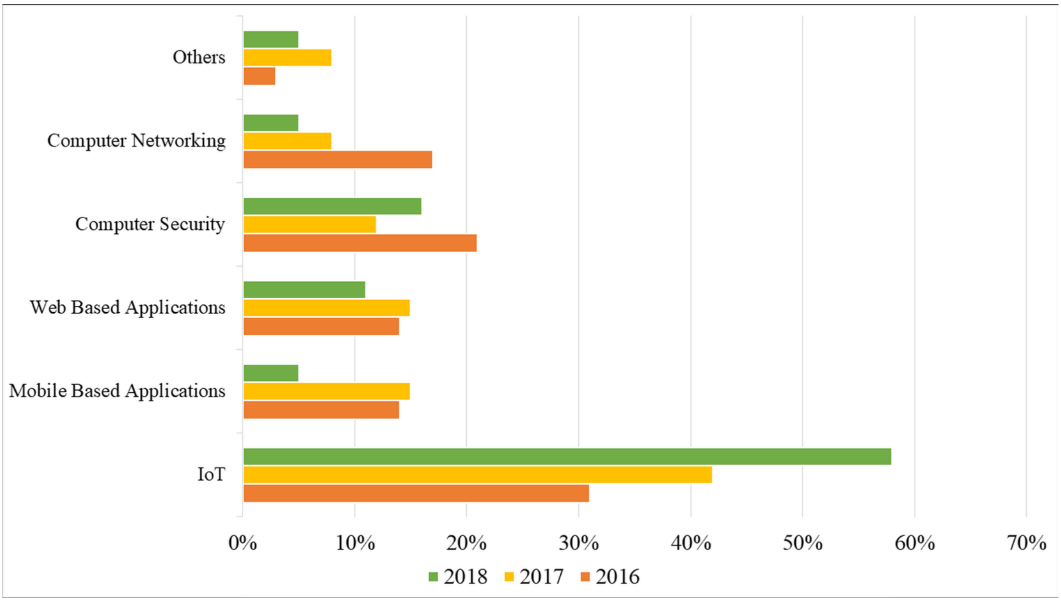
The inability to interoperate IoT with the traditional client-server network is a limitation to the knowledge and skills of networking students. Students need to practice with the concept of IoT so that they practically know how the connection between the devices and the hardware is being realized. Nevertheless, it is also comprehensible that in order to set up a platform in a form of space and equipment, not to mention the paperwork, budgetary, procedures, time and cost; are the main hurdle in achieving this aim. Hence, to compensate with time and cost, in providing the students the equipment and the platform for IoT learning purposes, this 'Smart Home' model serves as a platform for students to learn the basic foundation of IoT, the functions of the sensors, the set up and connectivity of circuitry, communication between sensors and microprocessor, system and web integration, etc.

SMART HOME MODEL

In every perspective, IoT solutions are growing increasingly to virtually all area of everyday lives as the field of an application IoT technologies and as they are tremendously dynamic and diverse. In an IoT environment, many of the things surrounding us gather information about us without our realizing it. Such as things embedded into objects, worn on our bodies, controlled with sensors, developed for intelligence, and created for data gathering capacity and communication. All these things communicate each other through the cloud, make decisions, and shared information. This kind of phenomenon can be created and integrated into a learning tool for learning purposes. For example, many researches uses smart home model and applications as a learning platform for IoT (Alaa, Zaidan, Zaidan, Talal, & Kiah, 2017; Suduc, 2018; Wortmann & Flüchter, 2015). An IoT smart home network mainly consists of physical devices that provide electronic sensors, software, and network connectivity inside a home (Alaa et al., 2017). People used to manually use all everyday things especially home appliances such as lamp, fan, television, bicycle and etc. People can rest more than before as the IoT concept will do everything that refers to the network interconnection of everyday objects generally (Xia, Yang et al. 2012).

A definition by Satpathy states; "a home which is smart enough to assist the inhabitants to live independently and comfortably with the help of technology is termed as smart home. In a smart home, all the mechanical and digital devices are interconnected to form a network, which can communicate

Figure 1. Final Year Project Domains for CS245 Students from the year 2016 to the year 2018



with each other and with the user to create interactive space" (Alam, Member, Reaz, & Ali, 2012). "Smart home technology" implies "a collective term for Information and Communication Technology (ICT) as used in houses, where the various components are communicating via a local network", which can later be used to "monitor, warn and carry out functions according to selected criteria" (Laberg T., et al. 2005).

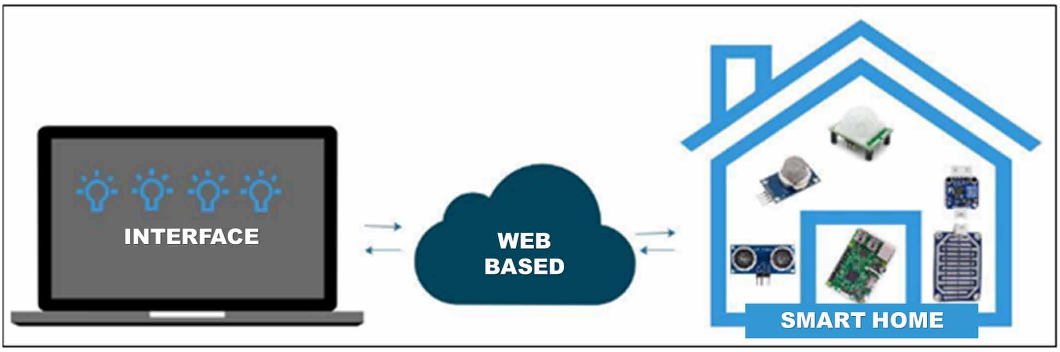
As mentioned earlier, smart home projects is a very much preferred project when it comes to practicing IoT; however so, smart homes can express different ideas, functions, and utilities. Smart homes are ranging into different divisions of specialization concentrating on the interests of researchers and user requirements and as well as expectations (Alam et al., 2012). There are levels of the "smartness" or approaches of these smart home models for example to enable appliances automation, home security and others, hence smart home is also referred to in other terms such as "remote-home", "intelligent-home", "home-automation system", "automated-home" and many more (Alaa et al., 2017; Gram-Hanssen & Darby, 2018; Marikyan, Papagiannidis, & Alamanos, 2018).

As an introductory platform for IoT learning, the smart home model is preferred, as so many other research projects (Adjih & Mitton, 2016; Risteska Stojkoska & Trivodaliev, 2017; Tan, Ker, & Abdullah, 2017). It is to embed the most basic IoT devices to integrate and communicate through a network connectivity for the purpose of practically learn the connectivity and functions of IoT in a form of the basic needs of a smart home. This smart home model is however being developed for the purpose of introducing and inspiring student to learn about IoT, hence presenting the use of the most basic IoT devices, its functions, as well as its integration with the microprocessor. A written guide or manual as well as a web-based interface to review the interactivities and conforming functions of the sensors embedded in the model were also prepared for ease of understanding.

GENERAL ARCHITECTURE FOR THE SMART HOME MODEL

The design of the smart home model includes the physical and logical layout, which consists of a circuit diagram. The physical layout will be the floor plan, while the logical layout shows the connected sensor to the raspberry pi 3 that acts as the main brain from the entire network. Figureure 2 depicts

Figure 2. General architecture of the smart home model



the general architecture in which the IoT devices or sensors are embedded in the smart home model that will be connected and controlled via the raspberry pi 3 and further integrated with a web-based system and accessible through the mobile device (laptop).

IoT Devices and Raspberry Pi 3

The main brain of this project that controls all the sensors was Raspberry Pi 3 Model B. The RPi3 is the third generation of Raspberry Pi that is built from Broadcom 2837 ARMv8 64-bit processor. It is more powerful than its predecessors that many applications can be used for and replaces the Raspberry Pi 2 Model B.

Sensors are devices that identify or calculate the physical property such as odor, boiling point, texture, density, and many other and records and specify or otherwise reply to it. In developing this smart home model, some very basic home appliances sensors are chosen and embedded in the model such as temperature sensor, PIR motion sensor, gas sensor, ultrasonic proximity sensor, and raindrop sensor. Buzzers and light emitting diode (LED) are also used as lights in the model as well as an alarm or warning indicator. The specifications of the sensors embedded in the smart home model are listed in Table 1.

Physical and Logical Layouts

The physical layout of the smart home model is constructed on a 2 by 3 feet wooden platform, and the buildup of the house is modeled using Lego bricks. The segmentation of the interior of the house and the top view of the real model is represented in Figure 3 and the logical design and the circuitry diagram of the architecture is represented in Figure 4.

The RPi3 is first setup with its raspbian operating system and the other sensors and its functions are involved by python coding. The model is utilizing NOOBS as an easy operating system which contains Raspbian. It also provides an alternative operating system that can be downloaded via an SD (Secure Digital) memory card and installed from the internet. This is to ensure that the Raspberry Pi is internet enabled and to further connects with the web interface. RPi3 is connected to the monitor using HDMI to VGA converter. A testing of the connection and the detection of each function from the sensors were tested from the RPi3 that is connected to the monitor using this converter. In this phase, each of the sensors is tested individually through each of its coded programs. As all of the sensors were successfully tested and operating as it should, the next phase is to setup the web-based interface, as explained in the next section.

Table 1. Smart Home Model Sensors

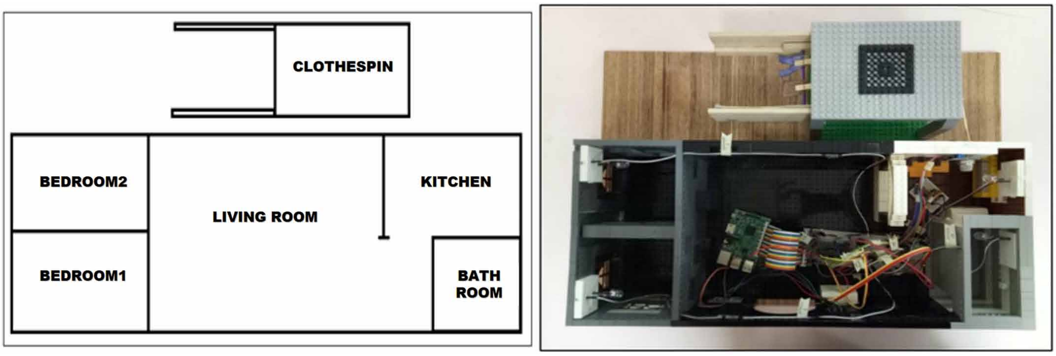
Name/Model	Function	Segmentation of embedment in the Smart Home model
MQ-2 Analog Gas Sensor	Sensitive in the detection of smoke and flammable gas such as LPG, butane, propane, methane, alcohol, and hydrogen. An analogue-to-digital converter (ADC) microchip, MCP3008 is used for this project.	Kitchen (Detection of gas leakage)
DS18B20 temperature sensor	DS18B20 digital thermometer provides 9-bit to 12-bit Celsius temperature measurements and has an alarm function with non-volatile user-programmable upper and lower trigger points.	All segments (Reads the temperature of each segment)
HC-SR04 Ultrasonic Proximity Sensor	HC-SR04 Ultrasonic Proximity Sensor recognizes object proximity or closeness using sound or vibration that having an ultrasonic frequency. The transmitters are used to generate and transmit electromagnetic waves, which give out a high frequency signal from ultrasonic sound, which reflects any nearby rigid objects. Some of that ultrasonic loud is cast back and recognized by the receiver on the sensor. The distance set for the detection of the vehicle is 20 centimeter (cm), in which then the buzzer will give the signal. If the distance is equal or less than 5 cm, the LED will be switched on together with the alarm from the buzzer, which warns the object to stop.	Garage (For easy vehicle parking)
Light-EmittingDiode(LED)	LED is used to produce bright quality light. Also used as light indicator for other sensors' responses. In this project, the LED acts as the light which will be used as PIR infrared light and buzzer as the device that give signal through the sound of the buzzer.	All segments (As the source of light for each segment)
Raindrop sensor	The raindrop sensor acts as a controller when raindrop descends through the down-pouring board and to compute rainfall intensity, which is the measurable amount of the rainfall. When a little amount of water on the rain board is dropped, the switch indicator will turn on and the clothesline will be under a rooftop. This is to stimulate the automatic retrieved of the clothes line in the event of raining to keep the clothes from getting wet.	Clothesline area (to detect rainfall and further signals retraction of the clothesline via motor and pulley)
Active Buzzer	An active buzzer generates sound itself.	Kitchen (Integrated with the MQ-2 Analog Gas Sensor to warn users of the detection of gas.)

Web-Based Interface

The web-based interface is developed to display the connections to the sensors, thus provides a GUI interface for user's convenience purposes. The GUI is ought to cater better understanding in the learning process where an individual could understand better when perceiving information through their own eyes.

In the development of this web-based interface, WebIOPi is being utilized. WebIOPi is a complete multi-tool to make "things" or IoT devices or sensors connect through a website. The web server is using the RPi3 IP address and on port 8000. In WebIOPi, it will have full access of all header pins (40 pins) on the web interface. For example, Figure 5 shows a circuit diagram of the DS18B20 temperature sensor that is connected to the RPi3 that is consists of one resistor that connected between the digital output (DO) and power supply (Vss) pins. The total of ohm that been used is 1k (Ω). The

Figure 3. Smart Home Model Physical Architecture



purpose of using 1k Ω resistor is to control the flow of current to the temperature as it can affect the temperature and be overheated.

JavaScript codes were written to connect between sensors and the website and XAMPP are used for establishing a connection to the database and PHP to open the web that acts as an interface. The web- based interface is shown in Figure 6 where each segment of the smart home model is being displayed. Each of the sensors is connected to the RPi3, which is integrated with the website; hence, data from the detection of the sensors are also displayed for the user's viewing through the web-based interface. An example of the detection of the current temperature is displayed on the web-based interface when requested via a click on the website is shown in Figure 7. The reading from the DS18B20 temperature sensor was also compared to readings from SHT21/HTU21 temperature and humidity sensor and an LM35 temperature sensor placed in the same room, which yields 98% of similarity and accuracy.

Figure 4. Smart Home Model Logical Architecture

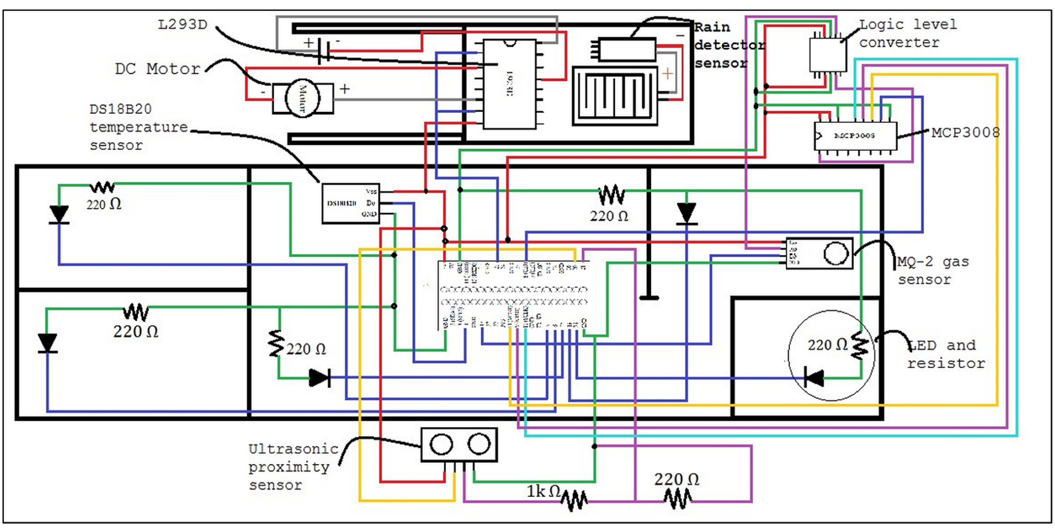
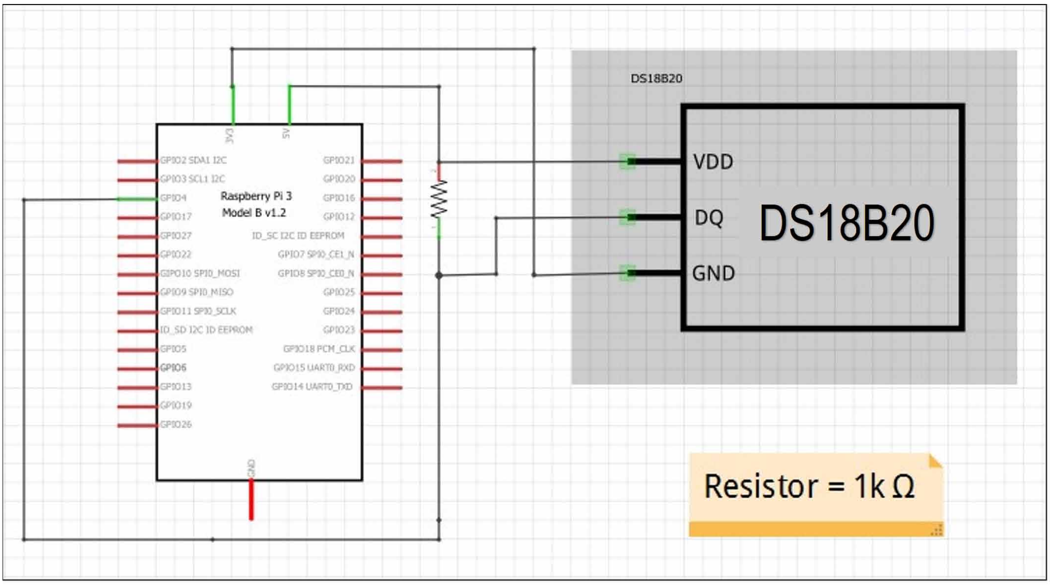


Figure 5. DS18B20 temperature sensor connected to RPi3 circuit diagram



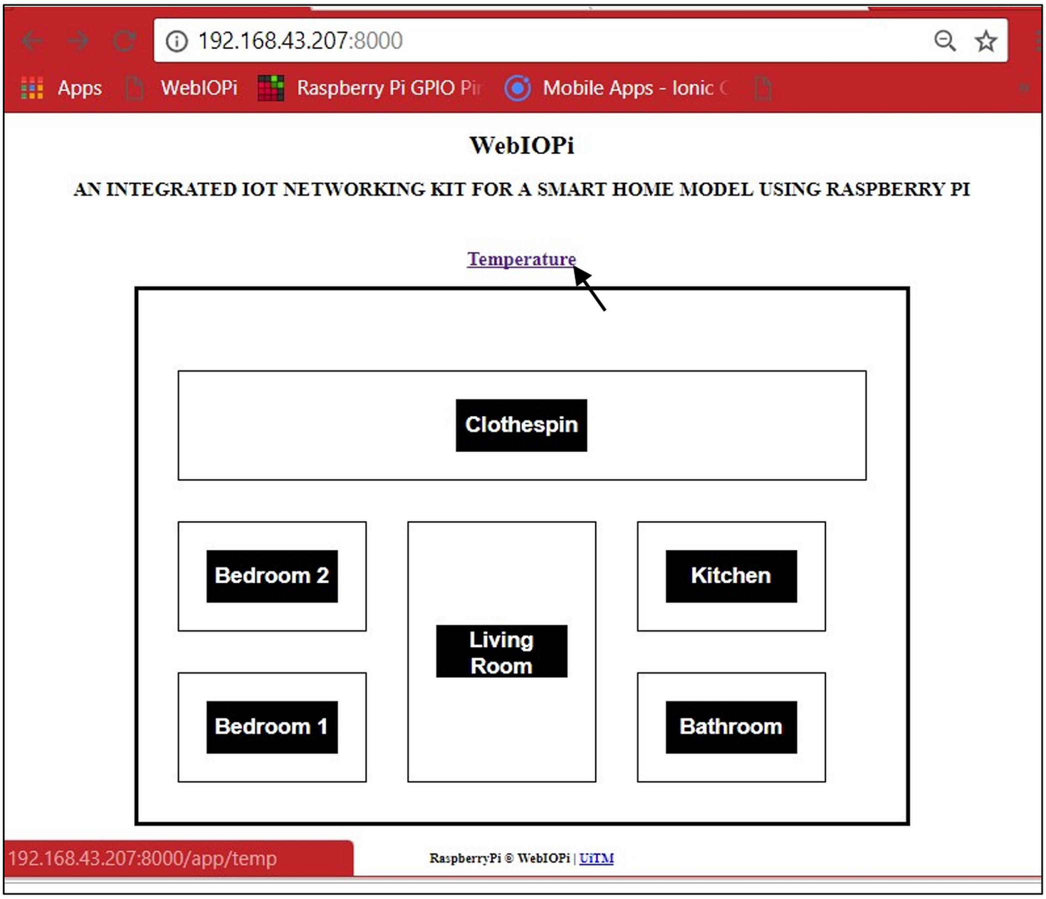
RESULTS OF USER ACCEPTANCE

On the completion of the Smart Home Model, a step-by-step setup manual of the model is produced and a simple user acceptance test is prepared. This user acceptance test is tested by respondents, which are the students from the Faculty of Computer and Mathematical Sciences in UiTM; selectively from the Computer Sciences background. Mathematical sciences students which is also students of the faculty were not selected to respond upon the assumption that it is not a requirement for these students to study computer sciences, hence discluded. The test was conducted for the duration of three days, which is during a Final Year Project Exhibition and the respondents were random students who visited the project's booth.

For the entire duration of the exhibition that runs on three days, the user acceptance test manages to acquire fifty voluntary students. Within this number, 76% or 38 respondents were from Computer Networking and Computer Netcentric programs, and the remaining 12 students or 24% of the respondents were from other computer sciences programs such as Information Technology, Computer Science and Computer Information System. Computer Networking and Computer Netcentric programs unlike the others covers some basic courses involving microprocessors and digital electronic. Hence microprocessors, sensors and circuitry may not be foreign to them. All respondents had completed their final year project in various domains.

All of the respondents were given a brief introduction of the project, a demonstration of how the model works, a test of the model and even a tryout to set the model from the manual provided. The session is conducted individually as well as in small groups of two to a maximum of five respondents. The respondents were later requested to individually fill in a Google form survey, which is aimed to conclude the effectiveness of the model in providing a platform for learning basic IoT. The survey aims to discover the level of interest the respondents have towards learning IoT and also the experience or competency level that they have despite no trainings or knowledge had been transferred or executed formally by the institution.

Figure 6. Smart Home Model Web-based Interface

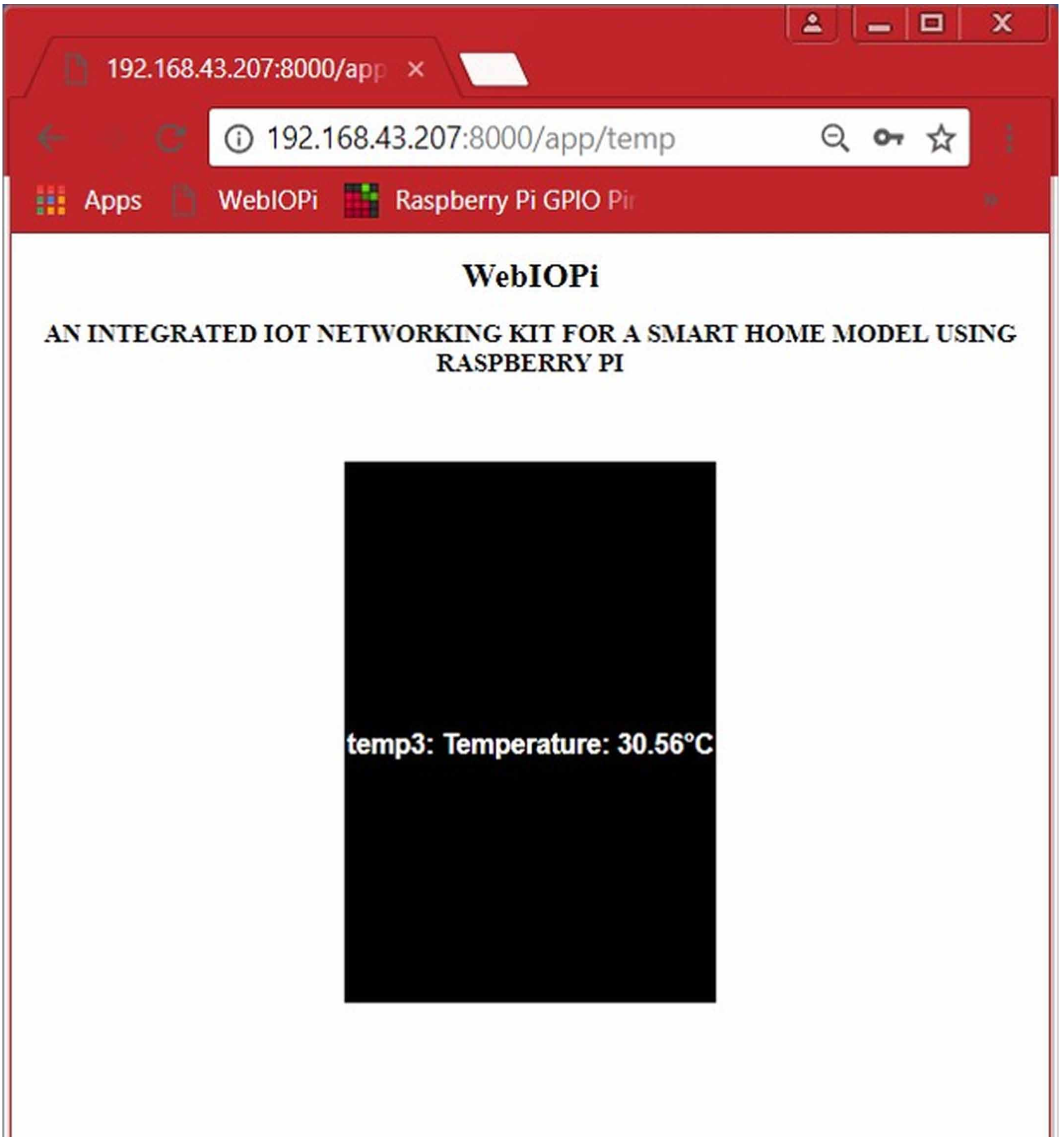


IoT Learning Interest and Competency

The first part of the survey inquires the levels of interest of the respondents in IoT. Inquiring their interest, however, highlights great interest in learning IoT, in which 86% responded that they are indeed interested, with 48% stating their interest at the highest scale. As a distinct separation of interest, 76% are interested while the remaining were mostly neutral with less than 5% statements of having no interest. This is a clear indication of the existing or the rising interest in the domain regardless of the minimal formal exposure provided by the institution.

As there were no IoT-based topic or courses offered in any of the computer sciences programs, the respondents were also inquired to state if they have had any exposure of any kind towards learning IoT. Exposure is explained to have done a simple IoT project before or prior starting their Final Year Project. The level of exposure is classified into four categories, beginning from unconscious incompetence, conscious incompetence, conscious competence and unconscious competence level. This is based on the four stages of competence, or the "conscious competence" learning model by Martin M. Broadwell. The conscious competence theory and related matrix model explain the process and stages of learning a new skill (or behaviour, ability, technique, etc.) which relates to the

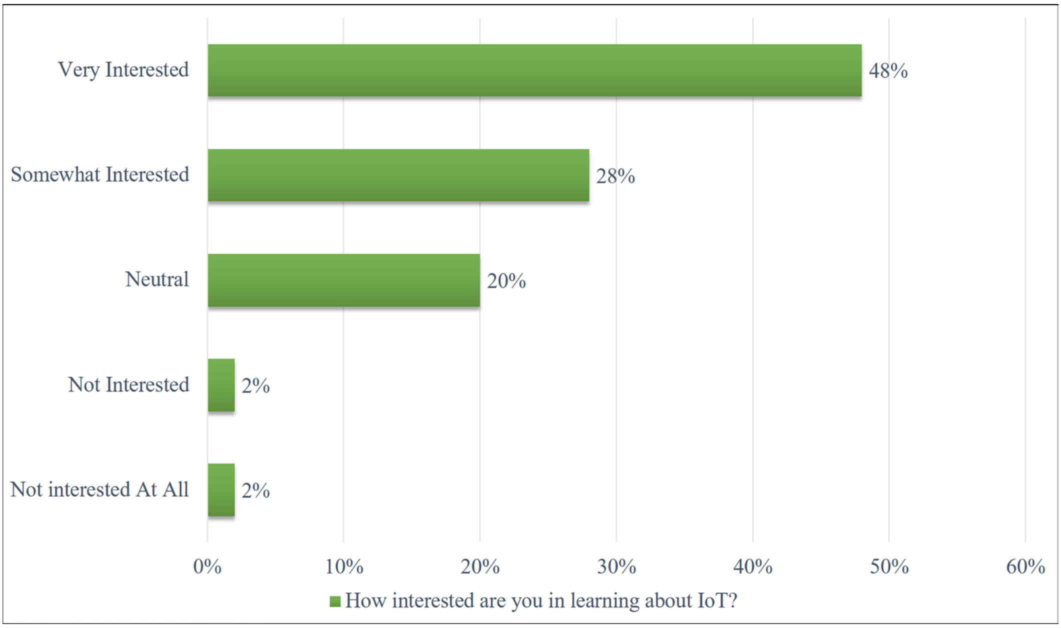
Figure 7. Temperature Reading from DS18B20 temperature sensor from Web-based Interface



psychological states involved in the process of progressing from incompetence to competence in having the knowledge and skills in a certain domain (Getha-taylor, Hummert, Nalbandian, & Silvia, 2012.). The description of the classification of each level concerning to this project is indicated in Table 2.

As a result of the conscious competence inquiry, 2% respondent responded that they had no prior knowledge nor skills pertaining IoT. Some claimed had never heard of the term "IoT". In the other hand, the vast majority of the respondents, which is 82%, summing up to 41 respondents are categorized in the conscious competence category in which they claim that they do acknowledge the existence of IoT, have a general idea of the technology domain, however does not attain the knowledge nor skills to be performing any tasks relating to it. The remaining 16% of the respondents are categorized in the conscious competence level, in which they claimed that they have minimal exposure to learning IoT, having basic knowledge of how IoT works and had performed at least one simple task relating

Figure 8. Students' Interest in Learning IoT



to IoT. Most of them claimed that they were self-taught from the internet while some from their peers. Nevertheless, none of the respondents participating in the survey were categorized as within the unconscious competence level.

Whilst it is easy to categorize the students based on their conscious competence level, evidently the challenge that emerges from these survey is clearly of the provisioning the students interest in this ever in-hype domain. There is indeed a requirement for fulfilling the students' interest in IoT which is in line with the demands of the Industrial Revolution 4.0 initiative of the country. Providing this interest with adequate knowledge and training could have a significant impact in developing unconscious competence students in research and various field relating to IoT.

Acceptance and Effectiveness of the Smart Home Model

In measuring the acceptance and effectiveness of the Smart Home Model, six survey questions were asked based on and relevant to the respondent's experience testing the model through the Google form survey. The respondents took a roughly average of 10 to 15 minutes to complete the survey questions. The acceptance and effectiveness were measured according to their experience levels, specifically;

1. Level of simplicity in using the model
2. Level of understanding of basic IoT operation from the model
3. Level of effectiveness of the Web-Based Interface in Assisting Learning
4. Level of convenience and ease of following the manual
5. Level of understanding IoT sufficiency after testing the model
6. Level of inspiration for learning IoT after testing the model

These levels were presented using a linear scale of 1 to 5, ranging from;

1. Scale 1 = Lowest level

2. Scale 2 = Low level
3. Scale 3 = Medium or moderate level
4. Scale 4 = High level
5. Scale 5 = Highest level

Table 2. Level of Competence

Level of Competence	Description
Unconscious Competence	Describe a respondent that has enough experience with the skill that he or she can perform it so easily as so that he or she is able to perform a task unconsciously. (This respondent has the skills to perform IoT tasks confidently, unsupervised, without help or guidance and to finish without any flaws or errors).
Conscious Competence	Describe a respondent that knows how to use the skill or perform the task, however, at this stage he or she is only able to do so with practice, focus and much effort. (This respondent practically could perform IoT tasks, however would need a lot of references, guidance and mostly time to do it right)
Conscious Incompetence	Describes a respondent that is conscious or aware of a certain skill or knowledge gap exists and understands the importance of attaining the new knowledge or skill. (This respondent is aware of the existence of IoT and is also aware of the importance of learning about IoT).
Unconscious Incompetence	Describes a respondent that does not know what he or she does not know. This respondent is not conscious nor aware that a skill or knowledge gap exists. (This respondent does not know about IoT and is not aware that he or she does not know about IoT)

Figure 9. Students' Prior Knowledge/Experience in Learning IoT (before FYP)

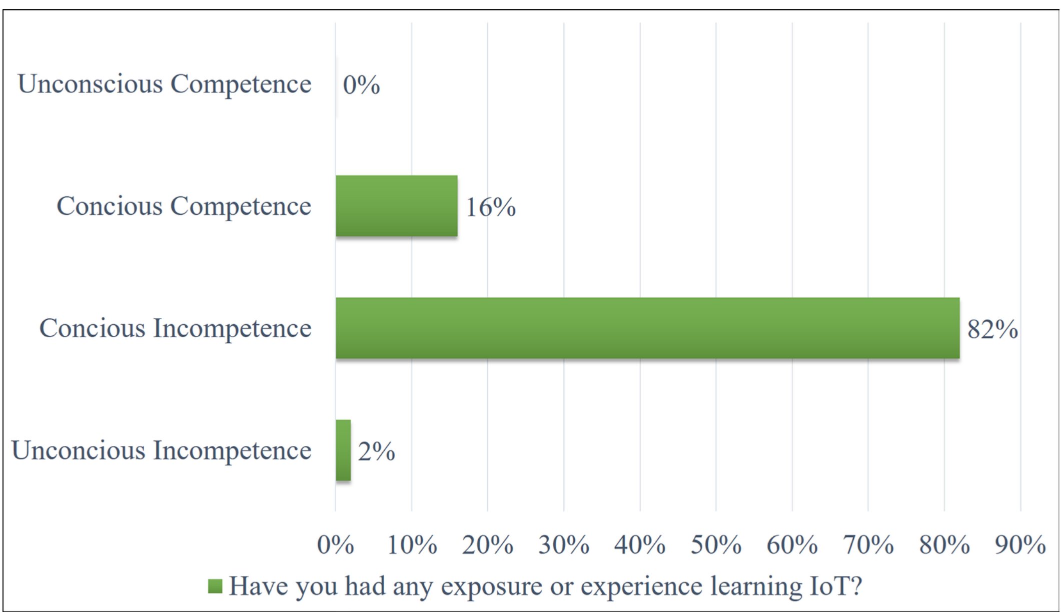
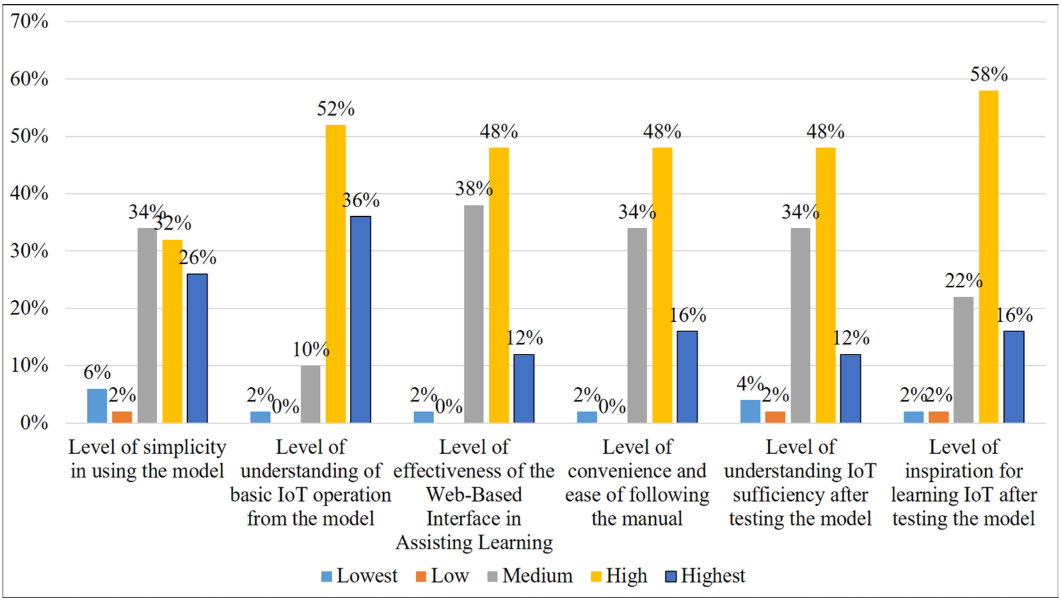


Figure 10. Smart Home Model User Experience Scale



The results of the survey in Figure 10 reveals an overall positive acceptance of all acquired levels, aggregating an average of 96% of acceptance of moderate to the highest scale for each level. The average of the highest scale of acceptance is at 20%, while non-acceptance at 4%.

From 84% of students within the incompetence levels (unconscious incompetence and conscious incompetence), 98% had claimed that they had grasp elementary understanding of basic or introduction to IoT operations from testing the model, and 96% stated that they are at least moderately to highly inspired to learning IoT after testing the model. The simplicity of the smart home model has been concurred at a high percentage of 92%, along with the sufficiency of the model in providing basic understanding about IoT, although the model could be improved for the latter. The web-based interface had also significantly assisting the students to learn about the effects of the IoT operations while the manual is also reported as not difficult to be used as guidance.

Comments and Suggestions from Respondents

The respondents had also requested to comment on how to improve the smart home model, as well as to give suggestions on how to inspire the learning of IoT amongst student. For the improvement of the smart home model, suggestions include building a better and bigger house model, preferably two or three stories built-up, adding more IoT functions such as air conditioner and conventional fan, television and etc. It is also recommended that the model be applied to a physical small space and use industrial grade sensors and equipment to further expand the functionalities of IoT set-up environment while increasing the QoE (Quality of Experience) in learning. There were also suggestions of integrating the model with more security features, physically and as well as in accessing the web interface. As for the aim of inspiring the learning of IoT, many recommend that the faculty offer free or low-cost short courses, while most are urging for the development of an IoT lab and facilities as well as the inclusion of IoT in their course's syllabus.

CONCLUSION

Students could grasp better basic theoretical and practical understanding through the utilization and experimental experience using this smart home model. Although the model was simple and have limited basic IoT devices embedded in it, this model is deemed adequate as an introductory kit for students to have their first exposure to learning about this state-of-the-art technology. An overall average of more than 90% positive responses of all level of acceptance for ease of use, impact of understanding of IoT, sufficiency of understanding basic knowledge and skills to perform IoT tasks and most importantly the inspiration of learning about IoT through the Smart Home model prepared. This is despite of having more than 80% of unconscious incompetence and conscious incompetence users or respondents testing the model. The guided manual and the web-based interface to assist understanding and as well as to reduce any intricacy that might appear to the first time learners has also significantly helped in understanding and utilizing the model to further inspire the learning of IoT.

The inclusion of IoT syllabus in computer sciences courses as well as providing facilities and space for learning, exploratory, development, and innovations of IoT is detrimental and demanded in today's education to equip students with the knowledge and the skills that are needed in almost any field today and definitely in the future.

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