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AN INTERNET OF THINGS-BASED E-LEARNING IMPLEMENTATION TO SUPPORT COLLABORATIVE LEARNING IN SCIENCE SUBJECT

Khairul Shafee Kalid[1]*, Wan Fatimah Wan Ahmad[1], Muhammad Shafiq Shahrul Amar[2], Dwi Sulisworo[3], Meita Fitrianawati[3], Arsyad Cahya Subrata[3]

[1]Computer and Information Sciences, Universiti Teknologi PETRONAS, Malaysia
[2]Creative Minds Group, Malaysia
[3]Physics Education Department, Universitas Ahmad Dahlan, Indonesia

Email: khairulshafee_kalid@utp.edu.my

ABSTRACT

The Science, Technology, Engineering and Mathematics (STEM) initiative in Malaysian Education Blueprint 2013-2025 aims to develop students with the necessary skills that could face the challenges of science and technology and to ensure Malaysia produces enough qualified graduates in STEM. Nonetheless, the number of students taking STEM subjects has been declining over the years. Many studies have investigated factors that lead to the decline. One of the factors is attributed to students' experience in class which the students perceive that STEM subjects are boring and dull. This study attempts to propose the use of the Internet of Things (IoT) as a teaching aid for science subjects to make the learning of science more interesting. This paper presents the design of Quickscience, a science e-learning system that leverages the use of IoT devices as a teaching aid. The IoT device captures time, distance, velocity, and acceleration data and stores the data on a database that resides in the cloud. This architecture supports collaborative learning as the data can be used by other students from different schools. The methodology of this study consists of three phases. The functional requirements of Quickscience were developed in Phase 1. Phase 2 is about designing, developing and testing the IoT device and the web-based e-learning system. Phase 3 is about evaluating the system in terms of usability and acceptance. The results include the analysis and design models and evaluation of Quickscience as a teaching aid. The findings indicate that teachers are open to the idea of using IoT platforms such as Quickscience as a teaching tool because they feel that it will enhance students' interest in learning science.

Keywords: *collaborative learning, educational technology, e-Learning, Internet of Things, Science, STEM*

INTRODUCTION

The Industrial Revolution 4.0 (IR4.0) has transformed the landscape of the Malaysian economy into a modern wave of the global technology economy. Education plays a crucial role in producing future professionals for IR4.0. Scientific and mathematical principles understanding, practical knowledge of technology and engineering and problem-solving skills are the quality needed in the future workforce [1]. Science, Technology, Engineering and Mathematics (STEM) education facilitates Malaysia's transformation into this science and technology-driven economy so that the nation is prepared to adapt and tackle the challenges in the era of IR4.0 [2]-[3]. The STEM initiative in Malaysian Education Blueprint 2013-2025 aims to develop students with the necessary skills which could face the challenges of science and technology and to ensure Malaysia produces enough qualified graduates in STEM [2].

According to National Council for Scientific and Research Development, Malaysia will need at least 500,000 scientists and engineers by 2020, but the present statistics disclose that there are only 70,000 registered engineers, which is only 17% of the figure [4]. Teachers' knowledge, attitude and readiness to teach STEM subjects are positive [5]-[6], but the current situation indicates that the number of youngsters who plan to pursue STEM fields in Malaysia is much less encouraging. Former Science, Technology, and Innovation Minister Khairy Jamaluddin stated that the number of students taking STEM has fallen short of the target. He quoted a report from Science Outlook Report for 2017, which indicates the annual tertiary education enrolment in STEM courses was 40 percent in 2016 from the targeted 60 percent. A report by the Ministry of Education stated that only 42% of middle school students in Malaysia chose to do Science, including technical and vocational programs at high schools [7].

Many studies have been conducted to investigate the factors that lead to the declining number of students' enrolment in STEM education. One of the factors contributing to these concerns is students' learning experience. To enhance students' learning experience in STEM, the use of technologies in teaching and learning seems to be an opportunity. Technologies such as mobile applications, virtual reality, and augmented reality have been adopted in teaching and learning. With the current COVID-19 pandemic situation, there are approximately 470 million educational mobile application downloads in the first quarter of 2020 [8]. Virtual reality and augmented reality applications enhance students' engagement by transforming the way educational content is being delivered. It can be said that different technologies serve different purposes. The use of the Internet of Things (IoT) as a tool in teaching and learning seems to be unclear. IoT, a technology in line with IR4.0, is not yet common in education, particularly in teaching and learning [9]. In the era of IR4.0, educators can use IoT devices as a teaching aid tool, given that it aligns to the topics they are teaching. Students will learn the topics and have fun in the process as they use the IoT devices to collect data. It is believed that the implementation of IoT technologies in education will bring great opportunities for primary school students to conduct activities and experiments, thus enhancing their learning experience [10].

This study explores the use of IoT in the teaching and learning of STEM subjects. The aim of this study is to develop a prototype of an IoT-based E-learning platform called Quickscience that displays data captured by an IoT device for the students to do experiments and other problem-solving activities assigned by the teachers. Quickscience supports collaborative learning because the data captured by the IoT device can be shared and accessed by other teachers and students from different schools. Teachers can also share learning materials, experiment sheets and other activity documents to Quickscience.

LITERATURE REVIEW

This section presents the literature of the study. This section begins with an overview of STEM, students' interest in STEM, and lastly, the use of IoT in teaching and learning is discussed.

Overview of STEM

Science, Technology, Engineering and Mathematics (STEM) is a curriculum that is based on the four disciplines-science, technology, engineering, and mathematics- in an interdisciplinary and applied approach. STEM approach allows students to examine and analyse the environments through investigation and problem-solving related to the actual world. STEM education plays a major role in establishing the quality of STEM-related professional labour production in a country. STEM is important because the economy is moving into the era of the Industrial Revolution (IR4.0). A report by PwC in 2015 indicates that the adoption rate of IR4.0 by companies is 33%, but it will peak at 72% in the year 2020 [11]. IR4.0 goes beyond computers and applications in IR3.0 by enhancing it with smart and autonomous systems fuelled by data and machine learning [12]. Thus, interdisciplinary thinking and qualified skills in the social and technical fields are required; thus, it is important for these two to be included in the education curriculum to prepare students to IR4.0 [13]. This indicates that to prepare the workforce for IR4.0, students' interest in STEM needs to pique in the early stage of their education.

Student's Interest in STEM Subject

In Malaysia, STEM education introduced in 2016, and it was officially implemented in schools in early 2017 [14]. Although the demand for labour related to knowledge and skills in STEM has increased, interest in science-related subjects continues to deteriorate. According to the Academy of Science, the number of students pursuing education in the science stream in secondary school decreased from 44% in 2011 to 21% in 2014. These statistics are alarming since it is far away from Higher Education Planning Committee's set target to achieve Science 60: Art 40 by 2020 [14].

One way to increase students' interest in STEM is by organizing programs outside the schools' boundary. Chittum et al. [4] studied the effect of an afterschool STEM program among students. Their findings show that the participating student's value for science improves compared to non-participants and that the experience positively impacted their perceptions about science as a field. Roberts et al.[15] studied the effect of STEM summer learning experiences in which the findings showed that such informal learning experiences influence students' interest in STEM. Kitchen et al. [16] stated that student's inclination toward a STEM career increases after participating in a program that allows the students to experience the relevancy of STEM in the real world. From the literature, it can be seen that after-school programs provide the opportunity for the students to experience STEM and expose them to the relevancy of STEM in the real world. This increases their interest in STEM and increases the possibility of choosing STEM-related careers. Nonetheless, this experience is achieved outside of the classroom in schools.

Students' learning experience of STEM subjects in the classroom is different from learning them outside of the classroom. Students feel that STEM discipline subjects are complicated, dull and tedious. Kennedy et al. [17] reported a study conducted by Pew Research Centre, which suggested that students do not pursue a STEM-related degree because of the difficulty of the subjects. Other factors include that the subjects are not useful in their careers and are too boring. In addition, the laboratory activities are usually like a recipe book that is highly arranged to teach students to design, execute and analyse data. Lakshminarayanan & McBride [18] mentioned that all of these create a passive classroom experience, and such learning does not encourage creativity, nor does it highlight the intellectual of science. This aspect tends to reduce students' learning experience and discourages them from pursuing their education in the science subject.

Collaborative Learning

Collaborative learning can be defined as a set of teaching and learning strategies promoting students in small groups of about two to five students to optimize learning for themselves and each other [19]. Hence, collaborative learning makes the students depend on each other in their quest for knowledge and makes learning more meaningful and interesting. When students work in a group, they will be part of the community, and therefore, everybody will give each other support. Studies have also shown that the students will learn better when the learning process is fun yet educational[20].

Existing studies indicated that collaborative learning could facilitate the growth of soft skills, increase academic performance, and enhance students' learning experience. It is considered one of the methods that can be implemented in the education learning process with collaborative learning and social engagement [21]. This study intends to adopt collaborative learning with IoT as its teaching tool to enhance students' learning experience.

The Use of IoT in Teaching and Learning

Internet of Things (IoT) refers to scenarios where network connectivity and computing capability extend to objects, sensors and everyday items not ordinarily considered to be computers, allowing these devices to generate, exchange, and consume data with minimal human interventions [22]. IoT is not a standalone technology, but it is a combination of various hardware and software technologies. Three IoT components enable seamless connections, which are: hardware, middleware, and software [1]. The hardware consists of sensors, actuators and embedded communication hardware that is used to monitor surrounding environments. Middleware is on-demand storage and computing tool used for data analytics that enables communications between applications and hardware devices. In contrast, the software is used to stimulate visualization that can be widely accessed on different platforms and applications. In last, it offers a solution that focuses on the integration of information technology is used to store, retrieve, and process data and communication technologies.

IoT in education can be classified into two categories. The first category is about providing courses to teach essential knowledge of computer science. The second category is about using IoT as a platform to enhance the academic infrastructure of a subject. Using IoT as the platform to enhance teaching and learning involves using sensors to capture data that can be used in teaching and learning. In the classroom, sensors can be used to capture data as parameters. These data can be used as part of science experiments, tutorials, or assessments. This can only materialize with an IoT platform that capture, store and access collected data.

There are many studies on IoT as a subject at schools or using IoT devices for managing the classroom. A smart classroom is an example of this. A smart classroom is an intelligent classroom environment fitted with a range of IoT devices and applications to monitor various parameters of the physical environment[7], [23]–[25]. Nevertheless, there seems to be a lack of study that uses IoT as a teaching and learning tool, let alone supporting collaborative learning. A good example of the use of IoT as part of collaborative teaching and learning is by Satu et al. [26]. The authors proposed a tier-based platform that is more holistic. The author's solution consists of three main components: Smart Management, Smart Contents, and Personal Devices. Smart Management is concerned with classroom management. Smart Content focuses on the learning management system, pedagogy, learning analytics, assessment, and digital library. Students use their personal devices outside of campus to access Smart Content. A collaborative learning approach is practiced on campus. Collaborative learning is achieved through flipped classroom approach. IoT devices such as camera, microphone, sound sensor and others are used in the classroom to monitor the learning process, identify problems, find the different types of students to identify their progress and compare their knowledge with other students.

METHODOLOGY

The learning materials uploaded into the Quickscience e-learning system come from the topic force and speed. These two topics were part of the Year 6 Science syllabus and were chosen because of their suitability for using IoT in teaching and learning. The e-learning system was developed according to the waterfall system development approach. Figure 1 shows the development phases of Quickscience, which consist of Phase 1: Analysis, Phase 2: System Design and Development and Phase 3: Evaluation.

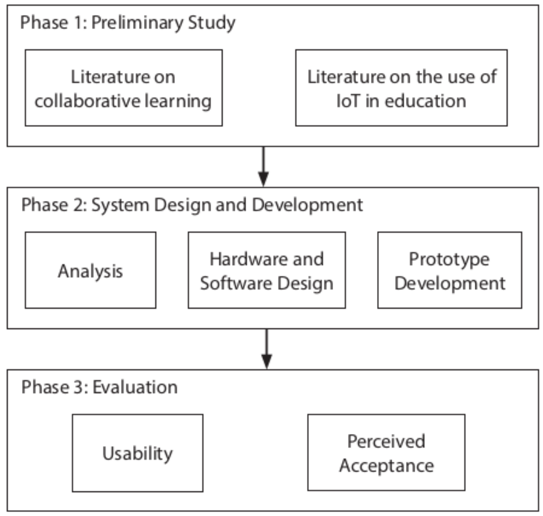

Figure 1 Quickscience development phases

In Phase 1: Preliminary Study, existing literature on collaborative learning and IoT in education were reviewed. The user requirements were gathered based on the output of the literature review, the user's experience in e-learning systems and the typical functionality attributed to e-learning systems. For example, in an e-learning system, teachers should be able to upload learning materials, and students should be able to view the IoT data and perform the learning activities based on the IoT data. These are the fundamental requirements of an e-learning system. To address the collaborative nature of the system, experiments, worksheets and IoT data must be made available for students from other schools to access and do the activities together. From the analysis of the requirements, the activity diagram can be developed to see the system's flow.

The development of the Quickscience e-learning system in Phase 2 includes developing the hardware and software. The tools to develop the website include

Visual Studio, XAMPP localhost as the web server, and Laravel framework as the framework to support front-end and back-end development. PHP, HTML, CSS and Javascript are the programming languages used in web development. Firebase and MySQL are selected as the database management system. Quickscience software consists of the Blynk software which is used to control the IoT device and the web-based e-learning. The hardware consists of global positioning systems, speed, and acceleration sensors. These sensors are attached to a robot car. The robot car is moved using a remote control and the sensors capture the data and send the data to the cloud server.

In Phase 3: Evaluation, the Year 6 students were invited through personal contacts to evaluate Quickscience in terms of its usability and potential use. On the other hand, the teachers were asked regarding their perception of the use of IoT in teaching and learning science. The questionnaire was developed using Google Forms and distributed to teachers using the Whatsapp application. The data was analysed using descriptive statistics.

QUICKSCIENCE PROTOTYPE DEVELOPMENT

This section discusses the prototype development of Quickscience. This section begins with an overview of Quickscience system architecture. Next, the activities and the outcome of all the three phases will be presented.

System Architecture

Figure 2 shows the system architecture of Quickscience. The users of Quickscience are the teachers and the students from various schools.

The teachers will upload learning materials to the e-learning system while students from different schools. The students will use the robot cars as part of their experiment activities from the learning materials. The time, distance, speed, and acceleration readings are recorded as the students move the robot car. The data can be viewed from the Quickscience website, and students can use the data to complete the experiments or perform problem-solving collaboratively. The data

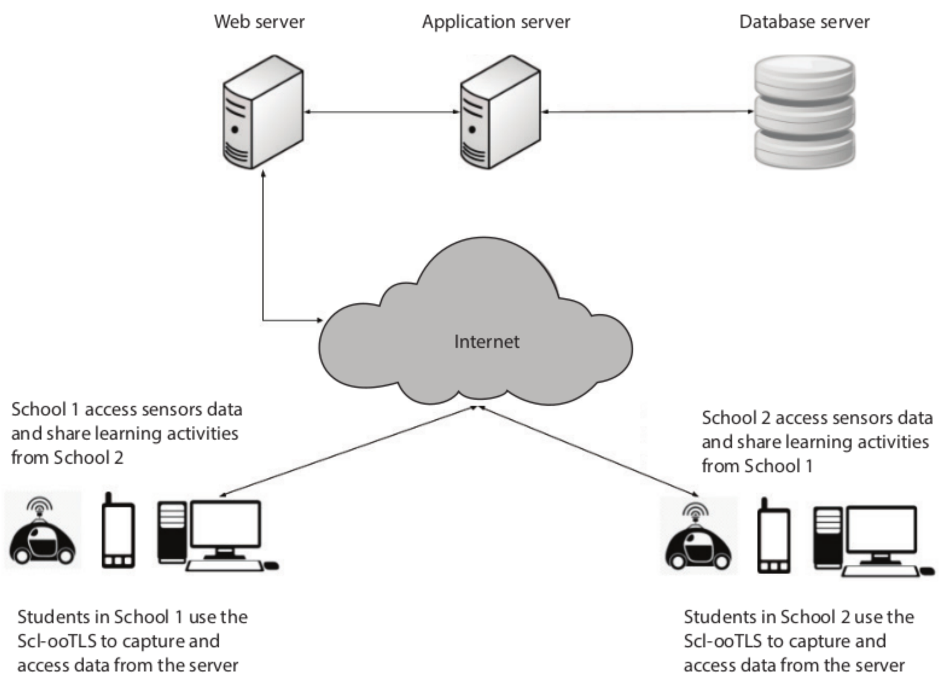

Figure 2 Quickscience System Architecture

are stored in a server accessible by other teachers and students from other schools. Teachers from other schools can upload and share their teaching materials with teachers from other schools. The Quickscience e-learning website provides teachers and students a platform to share and collaborate on any activities pertaining to the topic of speed and force.

It is proposed that each group of students in the class have access to the robot car. The intention is for the students to have practical activities and real-world experiences using the robot car. Through the robot car, students can get a better understanding of how speed and force work. Thus, having a fully assembled robot car instead of building the robot car from scratch makes more sense. Furthermore, building the robot car is not part of the learning objective of the two topics.

Phase 1: Analysis

Phase 1: Analysis activities include developing the functional requirement. The functional requirements were gathered through reviewing existing literature on collaborative learning, e-learning and IoT. The learning materials for Unit 6: Force and Unit 7: Speed were downloaded via the Internet to see the topics, content, and assessment. Table 2 shows the requirements of Quickscience web-based e-learning system.

Table 1 Quickscience functional requirements

Users	Feature
Teachers and Students	– Log in to the system – Update profile – Exchange messages – View sensor data (i.e., speed, time, location)
Teachers	– Upload teaching materials, experiment worksheets and activities – Share teaching materials
Students	– Perform learning activities

The teachers and students can view the data captured by the IoT sensors. The students will use the data as part of an experiment, or any other relevant activity document uploaded by the teachers. Figure 3 shows the activity diagram of Quickscience. The flow begins with the teachers logging to the website and uploading teaching materials such as experiments, exercises, handouts, and others. It is assumed that the students work in groups; thus, each group will have a username and password assigned by the administrator. The groups will log in and download the teaching materials. The teachers will demonstrate to the groups how to use the IoT device, the robot car. For example, teachers can use the robot car as a moving object and the sensors can capture the car's speed and distance. During the demonstration, the teachers can show how the data was captured. These data are stored in the database for the use of other teachers and students from other schools. The groups will play with the robot car view the data captured by the sensors robot car and answer the questions stated in the experiment document.

Phase 2: System Design and Development

The system design includes the hardware design and software and Quicksciene web-based e-learning system. The IoT device is a robot car equipped with sensors to measure speed, distances, and other relevant

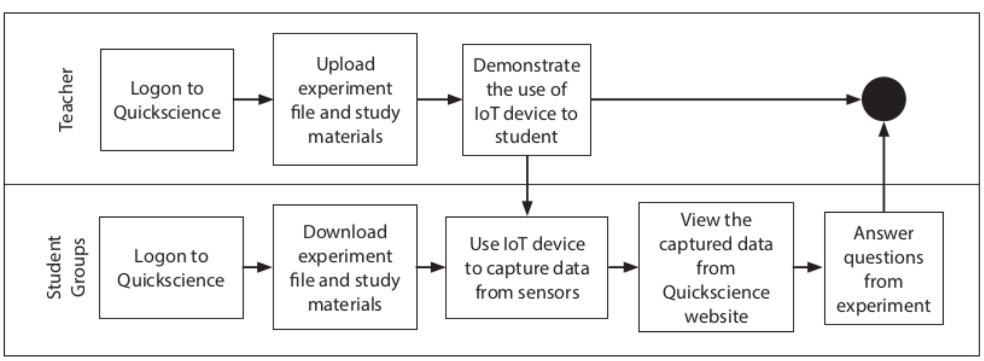

Figure 3 Quickscience activity diagram

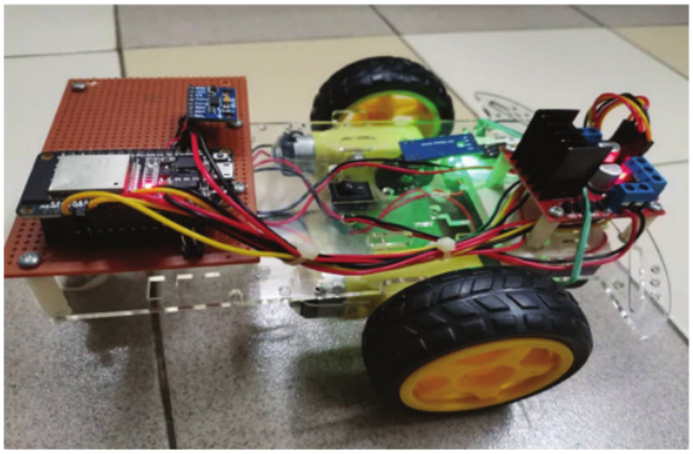

Figure 4 Quickscience robot car

data. The components attached to the chassis of the robot car are the accelerator sensor, L298N motor driver, WiFi ESP32 module, the speed code wheels, optical encoder and cell battery holder. Figure 4 shows the robot car used in this study.

The sensors attached to the chassis capture the data such as speed, time, coordinates, and others so that students can use them to calculate force or acceleration or any other variables. Arduino IDE was used as the platform to write the codes for the components on the robot car and Blynk software was used to write codes for the control of the car. For this study, the robot car can only move forward. The movement of the car was tested to see if the car moved as instructed and the data from the sensors was captured and stored in the database. The robot car control was developed using Blynk. Figure 5 shows the robot car control software developed using Blynk.

From Figure 5, the speed of the car is set using the slider bar. Then, the user will continuously press the 'Run' button and the car will move according to the speed that has been set. The car will stop once the user stops pressing the 'Run' button. After the car has stopped, the data from the sensors appear on the screen. The same data is also sent to the server for storage. The data from the car was validated to see if it had been captured and calculated correctly. The values are calculated manually to see if the values stored in the database are correct. The formula that was used for this is shown in Table 2.

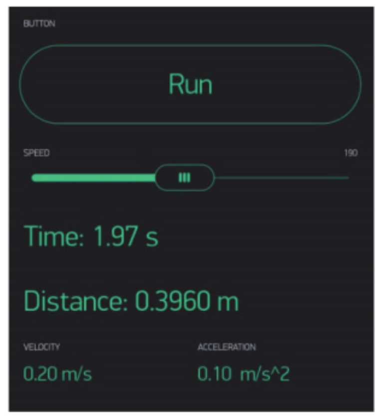

Figure 5 Quickscience robot car control

Table 2 Data validation formula

Variable	Unit	Formula
Distance	m	(Distance_val/20) *0.066 (changing diameter of the tyre from mm to m)
Velocity	m/s	Distance/final time
Acceleration	m/s	Velocity/final time
Total Final Time Taken	s	End time – Start time= Final time Final time /1000 (convert ms into s)

The readings from the IoT sensors were stored in Quickscience database. The database was developed using Google's Firebase Realtime Database. The movement of the robot car triggers the sensors to

Date	Time	Acceleration (m/s2)	Distance (meter)
Tuesday	23:13:17	0.03	1.65
Tuesday	23:13:29	0.03	1.85

Figure 5 Snippet of the real time data page

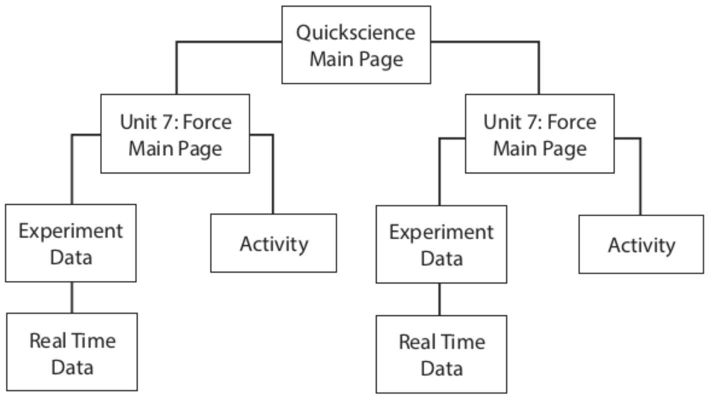

Figure 6 Quickscience web navigation diagram

capture the data on acceleration, distance, speed, and velocity. The data will then be sent to the Firebase server for storage. The students can access the Real Time Data page to view the data that has been captured. Figure 5 shows a snippet of the real time data in which only the values of acceleration and distance are shown.

This data can be used by the teachers and the students in doing the experiments and other activities. The web-based learning system allows teachers to present their content and upload teaching materials for the students to download. Figure 6 shows the web page navigation diagram of Quickscience.

The main page of the Quickscience consists of links that point to the Unit 6: Speed and Unit 7: Force pages. The pages follow the same design in which each page has a section on the content of the topic, activity, and experiment data. Teachers can upload activity files such as notes, exercises, quizzes, etc. Figure 7 shows a snippet of the main page for Unit 7: Speed.

The main page consists of an overview of the force, experiment data of the force and activity. The user can click on the experiment data and activity to direct them to the respective pages. Students can view or download the activity files on the Activity page. Figure 8 shows a snippet of the Activity page.

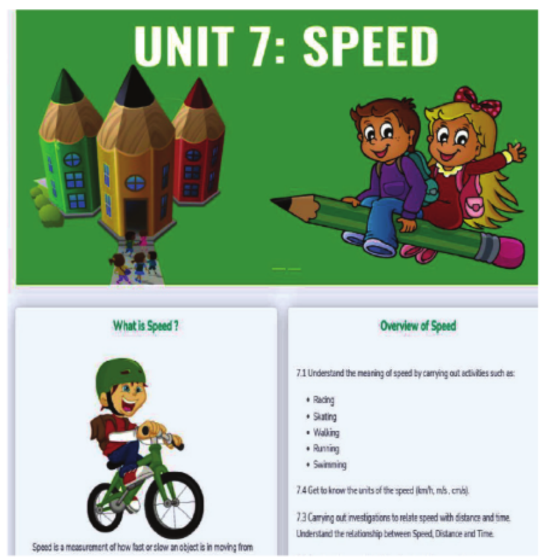

Figure 7 Unit 7 Speed Main Page

File Description	View	Download
Speed Exercise	View	Download
Calculating speed, time, distance, and acceleration	View	Download

Figure 8 Snippet of the Activity Page

Phase 3: Evaluation

The Quickscience was evaluated in terms of its usability and perceived acceptance. A total of 8 primary school students participated in the evaluation. Phase 3 was conducted during the movement control order (MCO); thus, the evaluation was conducted by demonstrating the robot car and the Quickscience website through Google Meet. To get their feedback, the participants were given a questionnaire for them to answer. The questions used a 3-point Likert scale with 3 indicating 'Agree' and 1 indicates 'Disagree'. Table 3 shows the mean score for the items in the questionnaire.

Table 3 Evaluation results

Item	n	Mean
The website is easy to navigate	8	2.9
Intention to use Quickscience	8	3
Perceived effectiveness in learning science	8	3
ScI-oTLS improves interest in science	8	2.9

The evaluation results indicated that the students agreed the Quickscience website is easy to use as it is user-friendly. The design philosophy of the Quickscience website is simplicity and easy to use with soft colours theme. In terms of acceptance, all participants have the intention to use Quickscience as a learning tool for science. This is expected as the use of a robot car that can be controlled through a smartphone could have piqued their interest. This is also corroborated by a mean score of 2.9 for the question of whether using Quickscience improves their interest in learning science. The participants also believed that learning with the IoT platform is perceived to be effective compared to the traditional method. Overall, the participants agree that using Quickscience makes learning science fun and interesting, thus supporting them in improving their interest in science and academic performance in the subject.

A total of 18 teachers responded to a survey on their perception of using IoT as a teaching aid in science subjects. The survey, which uses a 5-point Likert scale, was distributed through teacher's Whatsapp groups. The survey All of the respondents agree that the use of IoT in teaching science is beneficial to the students as it has the potential to enhance students' understanding and interest in science. Table 4 shows the perceived effectiveness of IoT as a teaching aid for science from the teacher's point of view.

From Table 4, teachers are open to the possibility of using IoT as a teaching aid for science subjects as they can see the effectiveness of IoT in improving learning activities for science subjects. Open-ended responses corroborating this finding that the teachers provided during data collection. In the questionnaire, an open-ended response was included to get the teacher's feedback on the possibility of adopting IoT technology as a teaching aid. Two of the teachers stated that, as a Science teacher, an IoT system is needed as it makes the teaching more interesting to the students, thus, improving students' performance. This finding is corroborated by (Maratha et al., 2021). The authors reported that 80% of the teachers that participated in their survey have shown interest in using IoT as a teaching aid and that the most important benefit of using IoT as a teaching aid is the impact that it brings to the students in terms of understanding of the subject and their interest towards science. Furthermore, the role of educational technology can address the lack of real-world exposure challenge. As one teacher stated, I may suggest to have students practice real-world situations through a computer simulator. So they will understand more easily and can visualize it in a bigger picture.

FUTURE WORK

The limitations of this study will be addressed in the future work. The participants of the survey are small. The intention is to get some insights into how teachers

Table 4 Perceived effectiveness of using IoT to teach Science

Item	n	Mean	Std Dev.	Remark
Effectiveness of IoT in improving learning activities for science	18	4.7	0.47	Positive
Possibility of using IoT in teaching science in schools	18	4.4	0.56	Positive

perceive IoT as a tool for teaching and learning. Generally, the teachers are open to the idea of using IoT in teaching and learning, but the sample is small. This study's future work also includes interviews with the teachers on the subject to strengthen the findings on students' perceptions. Apart from teachers, the Year 6 students need to be part of the survey as well. This is to see the impact of IoT on their learning of science.

The development of Quickscience system needs to be refined further. For example, the robot car can only move forward. Thus, it is an opportunity if the robot car cannot move in any direction. The design of the website is another opportunity. The design of the website's user interface is not based on user experience principles. Therefore, further validation on the user interface design is needed to ensure that the users have the best experience using the Quickscience website. Another future work is on the teachers' acceptance of using Quickscience as a teaching aid tool. It is important to understand their challenges and needs to ensure that they can use Quickscience.

CONCLUSION

The growth of IoT and cloud technologies have opened new possibilities for a smart school in Malaysia. This study presents the use of IoT in facilitating the teaching and learning of science subjects. This study intends to contribute to the decline of interest in STEM subjects in Malaysia, as highlighted by many studies. Existing studies also indicate that the student learning experience is one of the factors that contribute to this decline. Thus, this study attempts to make science learning more interesting by adopting IoT that provides data that can be used and shared with other teachers and students. Schools can collaborate in learning science because IoT provides the data but the connection and application as well.

Currently, the Arduino board and sensors have been developed and attached to a 2-wheel smart robot car chassis together with its Blynk program on the smartphone as the device controller. For the Sci-oLTS website, the focus is trying to extract the data that have been captured by the sensors and stored on the database and displayed on the website for the teachers to use.

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