

The Design of Sci-oTLS: An Internet of Things Platform to Support Collaborative Learning for Science subject in Primary School

Logadarshini Maratha¹, Khairul Shafee Kalid¹ and Wan Fatimah Wan Ahmad¹

¹Universiti Teknologi PETRONAS, Malaysia, {logadarshinni_24592@utp.edu.my, khairulshafee_kalid@utp.edu.my, fatimhd@utp.edu.my}

ABSTRACT

The Science, Technology, Engineering and Mathematics (STEM) initiative in Malaysian Education Blueprint 2013-2025 aims to develop students with necessary skills which could face the challenges of science as well as technology and to ensure Malaysia produces enough qualified graduates in STEM. Nonetheless, the number of students taking STEM subject is declining over the years. Factors that lead to the decline have been investigated by many studies. One of the factors is attributed to student's experience in class which the students perceived that STEM subjects are boring and dull. This study attempts to propose the use of Internet of Things (IoT) platform as a teaching tool for STEM subjects to make the learning of the subjects more interesting. This paper presents the design of Sci-oTLS, an IoT platform that supports collaborative learning of Science subject in primary school. The objective of this study is to propose the design of an IoT platform that supports collaborative learning in Science subject. The method of this study consists two phases. The first phase concerns with the distribution of a small survey to teachers to get their preliminary feedback on the use of IoT in teaching and learning of STEM. The second phase concerns with the design of the Sci-oTLS platform. The results indicate that teachers are open to idea of using IoT platform such as Sci-oTLS as a teaching tool because they feel that it will enhance student's interest in learning Science. The requirements and system architecture of Sci-oTLS are also presented in this paper.

Keywords: Internet of Things, IoT, Teaching and Learning, Education.

I INTRODUCTION

The Industrial Revolution 4.0 (IR4.0) has transformed the landscape of the Malaysian economy to a modern wave of global technology economy. Education plays a crucial role in producing future professionals for IR4.0. The scientific as well as mathematical principles understanding, practical knowledge of technology and engineering and; problem solving skills are the quality needed in future workforce (Ramli et al., 2017). Science, Technology, Engineering and Mathematics (STEM) education facilitates Malaysia transformation into this science

and technology-driven economy so that the nation is prepared adopt and tackle the challenges in the era of IR4.0 (Saleh et al., 2020). The STEM initiative in Malaysian Education Blueprint 2013-2025 aims to develop students with necessary skills which could face the challenges of science as well as technology and; to ensure Malaysia produces sufficient number of qualified graduates in STEM (Ministry of Education Malaysia, 2013).

According to National Council for Scientific and Research Development, Malaysia would 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 (Kamsi et al., 2019) but the current circumstances of Malaysia indicated that the number of youngsters who plan to pursue STEM fields in secondary, tertiary education is much less encouraging. Science, Technology, and Innovation Minister Khairy Jamaluddin stated that the number of students taking STEM has fallen short of target. He quoted a report from Science Outlook Report for 2017 which indicates the annual tertiary education enrolment in STEM courses was 40 per cent in 2016 from the targeted 60 per cent (Bernama, 2020). 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 (Shahali et al., 2017).

There are many studies that have been conducted to investigate the factors that lead to declining number of student's enrolment on STEM education. One of the factors that contributed to these concerns with student's learning experience. To enhance student's learning experience on STEM, the use of technologies in teaching and learning seem to be an opportunity. Technologies such as mobile application, virtual reality, augmented reality have been adopted in teaching and learning. With the current COVID-19 pandemic situation, there is approximately 470 million educational mobile application downloads in the first quarter of 2020 (Clement, 2020). Virtual reality and augmented reality applications enhances student's engagement by transforming the way educational content is being delivered. It can be said that different technologies serve different purpose. The use of Internet of Things (IoT) as a tool in teaching, and learning seems to be unclear. IoT, a technology that is

in line with IR4.0, is not yet common in education particularly in teaching and learning (Digiteum, 2020).

Thus, this study explores the use of IoT in the teaching and learning of STEM subject. The objective of this study is to determine the teacher's perception on adopting of IoT in their teaching and learning and to propose the design of IoT platform called Sci-oTLS that collects experiment data for teaching and learning. Sci-oTLS also supports collaborative learning because the data captured can be shared and accessed by other teachers and students from different schools. Through Sci-oTLS website, teachers can share learning materials and activities as well.

II LITERATURE REVIEW

This section presents the literature review of the study. This section begins with an overview of STEM. It is reported that the number of students in STEM related courses are declining, thus the next topic discussed in this section is regarding student's interest in STEM subjects. Lastly, the use of IoT in teaching and learning is discussed.

A. 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 (Hom, 2014). 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 to establish the quality of STEM-related professional labour production in a country. STEM is important because of the economy is moving into the era of 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 to 72% in the year 2020 (PwC, 2015). IR4.0 goes beyond computers and applications in IR3.0 by enhancing it with smart and autonomous systems fueled by data and machine learning (Marr, 2018). 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 (Pereira & Romero, 2017). This indicates that, to prepare the workforce for IR4.0, the interest of students on STEM need to pique in the early stage in their education.

B. Student's Interest in STEM Subjects

In Malaysia, the STEM education is introduced in 2016 and it was officially implemented in schools in the early of 2017 (Ramli et al., 2017). Although the demand for labour related to knowledge and skills in STEM has increased, interest in science related subjects continues to deteriorate. According to Academy of Science, the number of students pursuing

education in 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 (Ramli et al., 2017).

One way to increase student's interest on STEM is by organizing programs outside the boundary of the schools. Chittum et al. (2017) studied the effect of an afterschool STEM program among students. Their findings show that the participating student's value for science improves as compared to non-participant and that the experience had a positive impact on their perceptions about science as a field. Roberts et al. (2018) studied the effect of STEM summer learning experience in which the findings shown that such informal learning experience influence student's interest in STEM. Kitchen et al. (2018) stated that student's inclination towards a career related to STEM increases after participating in program that allow the students to experience the relevancy of STEM in the real world. From the literature, it can be seen afterschool programs provides the opportunity for the students to experience STEM and exposing 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.

Student's learning experience of STEM subjects in the classroom is different from learning it outside of the classroom. Students feel that STEM discipline subjects are complicated, dull and tedious. Kennedy et al. (2018) reported a study conducted by Pew Research Center which suggested that students do not pursue a STEM-related degree because of the difficulty of the subjects. Other factors include the subjects are not useful in their careers and the subjects are too boring. In addition, the laboratory activities are usually like a recipe book that are highly arranged to teach students to design, execute and analyse data. Lakshminarayanan & McBride, (2015) mentioned that all these create a passive classroom experience and such learning do not encourage creativity nor does it highlight the intellectual of science. This aspect tends to reduce the learning experience of students and discourages them from pursuing their education in the science subject.

C. Collaborative Learning

Collaborative learning can be defined as a set of teaching and learning strategies promoting of students in small groups about two to five students to optimize learning for themselves and for each other (Le et al., 2018). 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 done in a fun yet educational way (Ibrahim et al., 2015).

Existing studies indicated that collaborative learning could facilitate the growth of soft skills, increase academic performance, and enhance the learning experience of students. It is considered as one of the methods which can be implemented in the education learning process with collaborate learning and social engagement (Maria et al., 2018). This study intends to adopt collaborative learning with the use of IoT as its teaching tool to enhance student's learning experience.

D. The Use of IoT in Teaching and Learning

Internet of Things (IoT) refers to scenarios where network connectivity and computing capability extends to objects, sensors and everyday items not ordinarily considered to be computers, allowing these devices to generate, exchange, consume data with minimal human interventions (Kurelović et al., 2018). IoT is just not a standalone technology, but it is a combination of various hardware and software technologies. There are three IoT component that enables seamless connections which are hardware, middle ware, software (Aldowah et al., 2017). Hardware consists of sensors, actuators and embedded communication hardware that used to monitor surrounding environments. Middleware is on demand storage and computing tools which used for data analytics that enables communications between applications and hardware device. While software is used to stimulate visualization that can be widely accessed on different platforms and applications. In last it offers a solution that focused on the integration of information technology which 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 on computer science and the second category is about using IoT as a platform to enhance academic infrastructure of a subject (Gul et al., 2017). Using IoT as the platform to enhance teaching and learning involves the use of 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 a science experiments, tutorials, or assessment. 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 classroom. Smart classroom is an example of this. Smart classroom is an intelligent classroom environment fitted with a range of IoT device and application to monitor various parameters of the physical environment (Bagheri & Movahed, 2016). Nevertheless, there seems to be 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., (2018). The authors proposed a tier-based platform which is more holistic in nature. The author's solution consists of three main components which are Smart Management, Smart Contents and Personal Devices. Smart Management concerns 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. Collaborative learning approach is practiced on campus. The 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 learning process, identify problems, find the different type of students can use this to identify their progress, compare their knowledge with other students.

III RESEARCH METHOD

The methodology of this study involves of two main phases namely Phase 1: Preliminary study and Phase 2: IoT-based Learning System prototype. Figure 1 shows the methodology of the study.

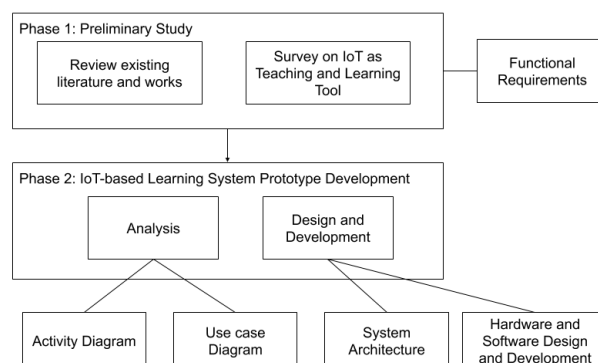


Figure 1. Methodology for Sci-oTLS

Phase 1 concerns with reviewing existing literature on the use of IoT in education and sending questionnaire to students and the teachers on their perception on the possibility of using IoT to support collaborative learning in Science subject for Year 6. Phase 2 is the design phase of the prototype. The system development methodology is based loosely on the agile concept. The development phases consist of two

sub phases namely Analysis and Design and development. For the analysis, the use case and activity diagram were developed based on the functional requirements that were obtained from Phase 1. The design phase includes the identification of the tools and the development of a system architecture, hardware, and software design. The components needed to develop the IoT hardware is shown in Table 1.

Table 1: Hardware Components for the IoT Device

Components	Description
Arduino board	The microcontroller board to read inputs from sensors
GPS 6M module	GPS receiver. This module detects the position of an object
ADXL 3xx Accelerometer	This module detects the acceleration of objects.
WI-FI module ESP 8266	To connect and send data through Wi-Fi network

The scope of this study is Year 6 Science subject. Two topics under Science were selected as the pilot for this study. The topics are Unit 6: Force and Unit 7: Speed. These topics were selected because of the content which seems possible to embed the use of IoT hardware and software in the teaching and learning. Using GPS and accelerometer sensors, data can be gathered, used, and shared with other schools. The system design focuses on the design of the Sci-oTLS learning website in which teachers can upload data required for speed and acceleration calculation and learning materials. The tools to develop the website includes Visual Studio, XAMPP localhost as the web server, Laravel framework as the framework to support front-end and back-end development. PHP, HTML, CSS and Javascript are the programming languages used in the web development. MySQL is selected as the database management system.

IV RESULTS AND DISCUSSION

This section presents the findings of this study. The findings are divided into two sections. The first section presents the findings of Phase 1. In Phase 1, a preliminary investigation was conducted which includes the distribution of small-scale survey to teachers and students on what they perceived IoT as teaching and learning tool. The second section presents the deliverables of Phase 2 which includes the use case and system architecture of Sci-oTLS.

E. Phase 1 Findings

A small-scale survey was distributed to teachers to know their perception on the use of IoT in teaching and learning in Science subject. The survey was distributed to teachers through personal contacts.

Figure 2 shows a bar chart that depicts teachers' perception in using IoT as a teaching and learning technology.

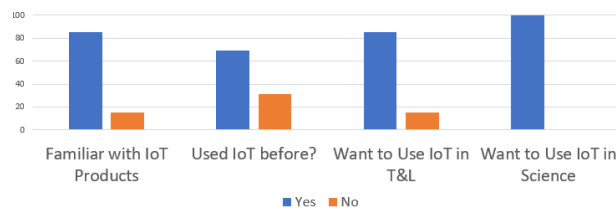


Figure 2. Teachers' Perception on IoT as a Teaching and Learning Technology

More than 80% of the teachers have shown interest in using IoT as a teaching and learning tool. For Science subject, all the teachers are open to the use of IoT as a tool to capture, share and use data for experiments in Science subjects. Figure 3 shows the impact of IoT as teaching and learning technology.

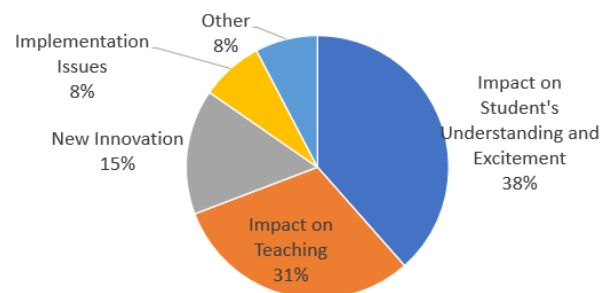


Figure 3. Impact of IoT as Teaching and Learning Technology

Based on Figure 3, 38% of the teachers believes that the use of IoT can provide impact on the student's excitement in learning science thus increasing their understanding on the subject as well. Only 31% of the teacher's response comes from the teacher's perspective. The teachers commented that IoT devices makes the capturing of data easier and quicker.

Teachers have always found ways to make their teaching exciting to the students. When the students feel that the subject is interesting to learn, it could help in their understanding of the subject. Teachers would try various methods which includes the use of technology. Teachers might have used gadgets and other technologies in their teaching thus, the findings of the survey are as expected. Nonetheless, it could be the teachers have not used IoT before so it could be interesting to see how this works out.

F. Phase 2 Findings

This study focusses on Unit 6: Force and Unit 7: Accelerator because these topics are seemingly convenient in embedding IoT as part of the technology for teaching and learning. The name of the IoT platform is called Sci-oTLS. Sci-oTLS consists of three major components namely Sci-oTLS IoT hardware, Sci-oTLS IoT software, Sci-oTLS IoT web-

based learning system. The hardware components of Sci-oTLS consists of the hardware required to develop the IoT device. Table 2 shows the requirements of the system.

Table 2: Sci-oTLS Website Functionality

Users	Feature
Teachers and Students	<ul style="list-style-type: none"> ● Login to the system ● Update profile ● Exchange messages ● View experiment data (i.e speed, time, location)
Teachers	<ul style="list-style-type: none"> ● Upload teaching materials ● Share teaching materials
Students	<ul style="list-style-type: none"> ● Perform learning activities

Figure 4 shows the system architecture of Sci-oTLS. The users of Sci-oTLS are the teachers and the students from various schools.

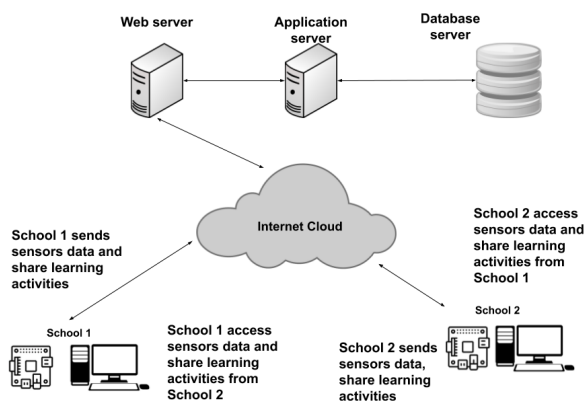


Figure 4. Sci-oTLS System Architecture

Each school will have a number of IoT devices. The IoT hardware consists of sensors to measure speed, distances, and other relevant data. The IoT devices can be attached to any moving objects in the class or outside of the class. The sensors will capture the data such as speed, time, coordinates, and others so that students can use to calculate force or acceleration or any other variables. The Sci-oTLS software concerns with programs to read these data from the sensors and send the data to servers for storage, share and access.

Sci-oTLS website is a web-based learning system that relies on the data capture by the IoT devices. This data can be accessed, shared and presented in meaningful way to facilitate teaching and learning of Science. The website also allows teachers to share and update learning activities with teachers and students from other schools. The teachers can be creative in thinking on how the data can be capture. For example, teachers can use radio-controlled car as a moving object and the sensors can capture the car's speed and distance. These data are stored to the database for the use of

other teachers and students from other schools. The IoT-based system will be evaluated in terms of its usability and acceptance. Participating schools will be equipped with the IoT hardware and software. and the hardware will capture the data are captured and stored in the database.

V FUTURE WORK

The limitations of this study will be addressed as the future work. The participants of the survey are small. The intention is to get some insights on how teachers perceived IoT as a tool for their teaching and learning. Generally, the teachers are open to the idea of using IoT in teaching and learning but the sample is small. The future work of this study also includes interview with the teachers on the subject to strengthen the findings on student's perception. Apart from teachers, the Year 6 students need to be part of the survey as well. This is to see the impact of IoT towards their learning of Science.

The development of Sci-oLTS is still a work in progress. 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 it on the website for the teachers to use.

VI 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 subject. This study intends to contribute to the declining of interest towards STEM subjects in Malaysia as highlighted by many studies. Existing studies also indicate that, student learning experience is one of the factors that contributing this decline. Thus, this study attempts to make the learning of science more interesting by adopting IoT that provides data that can used and shared to other teachers and students. Schools can collaborate in learning science because IoT not only provides the data but the connection and application as well.

In this study, a small-scale survey was distributed to teachers to know their views on IoT in teaching and learning and most of the participants are open to the use the technology for the sake of student's learning experience. The teacher's perceived that IoT has an impact on student's excitement in learning science and also enhances student's understanding of the subject. The scope of prototype development is Unit 6: Force and Unit 7: Speed as these two topics opens up opportunity for the use of IoT device to capture data. The Sci-oTLS database store the data and the website displays it for the teacher to use it as part of the

student's learning activities. The development work will continue, and the limitation of this study will be addressed in future work.

REFERENCES

- Aldowah, H., Rehman, S. U., Ghazal, S., & Umar, I. N. (2017). Internet of Things in higher education: a study on future learning. *Journal of Physics: Conference Series*, 892(1), 12017.
- Bagheri, M., & Movahed, S. H. (2016). The effect of the Internet of Things (IoT) on education business model. *2016 12th International Conference on Signal-Image Technology & Internet-Based Systems (SITIS)*, 435–441.
- Bernama. (2020, November 9). *Low number of STEM students worrying - Khairy*. <https://www.bernama.com/en/general/news.php?id=1899173>
- Chittum, J. R., Jones, B. D., Akalin, S., & Schram, A. B. (2017). The effects of an afterschool STEM program on students' motivation and engagement. *International Journal of STEM Education*, 4(1), 11.
- Clement, J. (2020). *Worldwide mobile education app downloads from 1st quarter 2017 to 1st quarter 2020, by platform*. <https://www.statista.com/statistics/1128262/mobile-education-app-downloads-worldwide-platforms-millions/>
- Digiteum. (2020, April 6). *How IoT Is Used in Education: IoT Applications in Education*. <https://www.digiteum.com/iot-applications-education>
- Gul, S., Asif, M., Ahmad, S., Yasir, M., Majid, M., Malik, M. S. A., & Arshad, S. (2017). A survey on role of internet of things in education. *International Journal of Computer Science and Network Security*, 17(5), 159–165.
- Hom, E. (2014, February 11). *What is STEM Education?* <https://www.livescience.com/43296-what-is-stem-education.html>
- Ibrahim, N., Shak, M. S. Y., Mohd, T., Zaidi, A., Yasin, S. M. A., & othes. (2015). The importance of implementing collaborative learning in the English as a second language (ESL) classroom in Malaysia. *Procedia Economics and Finance*, 31, 346–353.
- Kamsi, N. S., Firdaus, R. B. R., Razak, F. D. A., & Siregar, M. R. (2019). Realizing Industry 4.0 Through STEM Education: But Why STEM Is Not Preferred? *IOP Conference Series: Materials Science and Engineering*, 506(1), 12005.
- Kennedy, B., Hefferon, M., & Funk, C. (2018, January 17). *Half of Americans think young people don't pursue STEM because it is too hard*. <https://www.pewresearch.org/fact-tank/2018/01/17/half-of-americans-think-young-people-dont-pursue-stem-because-it-is-too-hard/>
- Kitchen, J. A., Sonnet, G., & Sadler, P. M. (2018). The impact of college- and university-run high school summer programs on students' end of high school STEM career aspirations. *Science Education*, 102(3), 529–547.
- Kurelović, E. K., Tomljanović, J., & Kukuljan, D. (2018). Introducing the Internet of Things to Computer Science Students. *International Conference on Science and Education (IconSE) 2018*.
- Lakshminarayanan, V., & McBride, A. C. (2015). The use of high technology in STEM education. *Education and Training in Optics and Photonics: ETOP 2015*, 9793, 97930C.
- Le, H., Janssen, J., & Wubbels, T. (2018). Collaborative learning practices: teacher and student perceived obstacles to effective student collaboration. *Cambridge Journal of Education*, 48(1), 103–122.
- Maria, M., Shahbodin, F., & Pee, N. C. (2018). Malaysian higher education system towards industry 4.0—current trends overview. *AIP Conference Proceedings*, 2016(1), 20081.
- Marr, B. (2018, September 2). *What is Industry 4.0? Here's A Super Easy Explanation For Anyone*. <https://www.forbes.com/sites/bernardmarr/2018/09/02/what-is-industry-4-0-heres-a-super-easy-explanation-for-anyone>
- Ministry of Education Malaysia. (2013). *Malaysia Education Blueprint 2013-2025*.
- Pereira, A. C., & Romero, F. (2017). A review of the meanings and the implications of the Industry 4.0 concept. *Procedia Manufacturing*, 13, 1206–1214.
- PwC. (2015, April). *Industry 4.0: Building the Digital Enterprise*.
- Ramli, N. F., Talib, O., & others. (2017). Can education institution implement STEM? From Malaysian teachers' view. *International Journal of Academic Research in Business and Social Sciences*, 7(3), 721–732.
- Roberts, T., Jackson, C., Mohr-Schroeder, M. J., Bush, S. B., Maiorca, C., Cavalcanti, M., Schroeder, D. C., Delaney, A., Putnam, L., & Cremeans, C. (2018). Students' perceptions of STEM learning after participating in a summer informal learning experience. *International Journal of STEM Education*, 5(1), 1–14.
- Saleh, S., Muhammad, A., & Abdullah, S. M. S. (2020). STEM project-based approach in enhancing conceptual understanding and inventive thinking skills among secondary school students. *Journal of Nusantara Studies (JONUS)*, 5(1), 234–254.
- Satu, M. S., Roy, S., Akhter, F., & Whaiduzzaman, M. (2018). IoLT: An IoT Based Collaborative Blended Learning Platform in Higher Education. *2018 International Conference on Innovation in Engineering and Technology (ICIET)*, 1–6.
- Shahali, E. H. M., Ismail, I., & Halim, L. (2017). STEM education in Malaysia: Policy, trajectories and initiatives. *Asian Research Policy Science and Technology Trends*, 122–133.