Exploratory of Electrical Learning Kit for STEM Application

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Abstract. Throughout the year, the implementation of the traditional approach (lecture-based) in the teaching and learning process seems to be less effective in increasing the interest among students towards the STEM subjects. Conversely, the use of practical learning method emphasizes on the psychomotor domain so that readers gain a clearer and more effective understanding. Thus, the aim of this paper is to investigate and exploratory the unique approach in implementation the learning kit where the students will increase their understanding towards the fundamental of electrical engineering. The effects that influenced the development process of learning kit is discussed and provided the ideas to build a quality learning kit for students who involved in STEM.

1. Introduction
Learning kit is very crucial in the process of teaching and learning. It can assist the process of sharing knowledge among the students with respect to the subject taught. The use of learning kit increases the student’s interest in learning the STEM subjects and assist them to learn electrical engineering through a misleading experience at the same time. The main purpose of learning it development is to help student understand the subjects more easily and systematically [1].

The process of teaching and learning in Electrical Engineering topics consists of two parts which are theoretical and practical. In order to master the subject, students are encouraged to have strong basic knowledge about the related subjects. By doing that, students will be able to face more high-level studies in the electrical engineering field. However, the level of difficulties in the subjects sometimes makes them study only to pass the exam without truly understand the content in the studies.

In addition, knowledgeable students somehow rely on the effectiveness of how teachers use the appropriate learning kits towards their teaching process. Apart from that, the way of how the subject is delivered also affects the students. The failure of delivering the subject causes the students to assume the subject to be difficult to understand.

In this chapter, the summary of studies related to this project is discussed. The studies included the
topics in sciences and electrical engineering that is compulsory for students in schools and universities. Apart from that, the implication of practical learning in the teaching and learning process will be compared to the traditional (lecture-based) to observe the effectiveness towards the education system. Next, the STEM application also will be discussed along with the subject related and the critical topics in Electrical Engineering that affects the interests among the students towards the subject. Then, the influence of the coloured image in the textbook, the QR code features and the use of video learning in teaching process will be elaborated to enhance the quality of the learning and teaching process.

2. STEM Application

David W. White [2] mentioned that STEM was primarily used in engineering firms in order to generate revolutionary technologies such as light bulbs, machines and automobiles. Nowadays, many countries heading towards innovation as they make a lot of improvements in their school system by emphasizing the teaching of Science, Technology, Engineering and Mathematics more vital [3].

E. Sujarwanto et. al [4] mentioned that the purpose of STEM is to prepare students with the development of science and technology, be ready for the career life and able to solve problems. In the application of STEM should integrate at least two disciplines. For example; i. The application of Science-Technology, ii. The application of Science-Engineering, and iii. The application of Science-Mathematics. The examples of STEM applications performed are given in Table 1;

| Mathematics: Learning Field | Science: Subject Field | Electrical Engineering | Technology | Skills |
|-----------------------------|------------------------|------------------------|------------|--------|
| Conversion Geometry         | Wind Energy            | Electrical Motor, Energy | Wind Power Generator |
| Problem                     | Chemical Reactions     | Electrical Power       | Rocket, Rocket Launcher |
| Algebra, Geometry, Calculus| Electricity, Physics   | Control System, Electrical Motor | Robot |
|                             |                        | Control Systems        | Medical Machine |

3. Student’s Perspective in Electrical Engineering

The high-quality graduates in the engineering field is very indispensable due to the growth of technology. Dianne Q. Nguyen et al. [5] found in her research that the requirement of the general and specific skills for an ideal engineer as shown in Figure 1.
Figure 1: Skills Required and the Characteristics of Ideal Engineer

The lack of understanding of the fundamental has made the students less interested in Electrical Engineering subjects. Aharon G. et al. [6] stated that most students assume that the basic electrical circuits course does not reflect a deep understanding of the discipline of electrical engineering. Dianne Q. Nguyen et al. [5] recognized the lack of appeal of subject contents, the method of delivery, passion, and basic knowledge of teachers as one of the factors that contribute to the downward trend in the number of engineering students.

In addition, Tatiana V. [7] had been surveyed the common misunderstandings of basic electricity revealed that student from the first year until last year often misunderstood about the difference between the voltage and current, the definition of electricity and the concept of ‘dead’ battery.

4. Critical Topics in Electrical Engineering

Electrical Engineering is a broad field that deals with the technology of electricity and often includes electronic engineering. According to Tom C. et al. [8], the majority of electrical engineering students spend approximately the first two years in developing a strong foundation in subjects such as math, physics basic circuit theories for both analog and digital domains. The author also mentioned that there are three pillars of core competencies which are; i. Signal and system, ii. Electronics and iii. Electromagnetic. Figure 2 shows the general concepts in Electrical Engineering.
5. Electrical Curriculum in Primary and Secondary Grades

The science curriculum is designed by the Ministry of Education in order to develop the opportunity to gain scientific knowledge, increase the ability in critical thinking skills, and able to apply the knowledge in daily life based on the Educational Development Plan for Malaysia from year 2001 to 2010. According to the Trends in International Mathematics and Science Study (TIMSS) 2015, the curriculum is categorized into three domains:

- **Scientific Knowledge**: Include the concepts, facts, rules, and principles.
- **Skills**: Involvement of scientific and critical thinking skills.
- **Scientific Attitudes and Values**: Development through experiential learning.

Table 2 shows the syllabus of science curriculum for primary and secondary grades based on Ministry of Education.

**Table 2**: Syllabus of the Electrical Curriculum for Primary and Secondary Grades adapted from Ministry of Education

| Main topics | Grade       | Year        | Subject                                      |
|-------------|-------------|-------------|----------------------------------------------|
| Electricity | Primary     | Standard 5  | Chapter 7                                    |
|             | Lower Secondary | Form 2    | Chapter 7                                    |
|             | Lower Secondary | Form 3    | Chapter 6                                    |
|             | Upper Secondary | Form 5    | Physics (Chapter 2)                          |
| Energy      | Primary     | Standard 5  | Chapter 5                                    |
|             | Lower Secondary | Form 2    | Chapter 7                                    |
| Magnet      | Primary     | Standard 3  | Chapter 5                                    |


6. Topics related to Electrical Engineering for Higher Education (Diploma & Degree Level)
The purposes of Electrical Engineering programme is to equip students with a full understanding of the fundamental theories along with the concepts in electrical engineering. J. M. Jornet [9] also highlighted the foundation of physical science, mathematics, computing, and technology to be added in understanding the subjects. Table 3 shows the syllabus on engineering topics covered for diploma and degree level.

| Main topics       | Level                  | Year | Subject            |
|-------------------|------------------------|------|--------------------|
| **Electricity**   | Diploma                | 1    | Electrical Circuit |
|                   | Degree in Engineering  | 1    | Electrical Circuit |
|                   | Degree in Engineering  | 2    | Electrical Technology |
| **Energy**        | Degree in Engineering  | 2    | Electrical Technology |
|                   | Degree in Engineering  | 2    | Generation & Distribution |
| **Magnet**        | Degree in Engineering  | 2    | Theory of Magnet   |
|                   | Degree in Engineering  | 2    | Electrical Technology |
| **Electrical Motor** | Degree in Engineering    | 2    | Generation & Distribution |
|                   | Degree in Engineering  | 2    | Electrical Technology |
|                   | Degree in Engineering  | 3    | Motor & Generator  |

7. Practical Learning
Practical learning is a combination of education and work known as cooperate education [10]. Robin M. [11] in his book defined practical learning or wok as any teaching and learning activity that involves the students to observe and manipulate the real object and materials. Upon the practical activity, the students will have a discussion of the observations whether their activity succeeds or fail. The author also added that practical tasks should act as communication for the students’ scientific knowledge development instead of acts as opportunities for inquiry. Figure 3 shows the Sustainable Development Goals that have been developed by Division for Sustainable Goals (DSDG).
The learning styles influences students’ understanding of the subject they have learned. Mei C. L. et al. [13] reported that the laboratory investigation (practical learning) enhances the students’ behaviors such as positive attitudes, encouragement, and interest towards learning in related subjects. Conversely, the theoretical learning approach affects the interest of students. Thus, they become not excited and finally not understand the subjects.

Degang Shi [14] analyzed that students that applied practical learning had dramatically improved the students’ result in the exam. Traditional education is still considered a good system that can be implemented in the education system. However, the rapid growth of technology had demanded the people especially graduates to have strong capability skills resulting in traditional education to become unsuited to the requirements of modern society.

The United Nations Department of Economic and Social Affairs (UNDSEA) stated that the efforts in providing the effective teaching methods is related to the sustainable development goals UNESCO specifically in Leading SDG 4: Quality Education [12]. In addition, the Inter-Agency and Expert Group on SDG Indicators (IAEG-SDGs) had stated that by the year of 2030, the number of youth and adults that have relevant skills such as technical skill increases for employment, eligible jobs and entrepreneurship as one of global target indicators of the Leading SDG 4: Quality Education.

On top of that, different students have their own learning styles. By knowing their own learning styles, the process of learning will become easier and successful. Hawkar A.A. [15] in his paper listed the classification of learning styles which are;
- Visual versus verbal
- Auditory learners
- Kinesthetic or tactile learners
- Intuitive versus sensing
- Global versus analytic
- Individual versus group preferences

The practical learning is being applied among the kinesthetic or tactile learners and analytic learners. As for the kinesthetic learners, they prefer to work with touchable objects and move around during work while the analytic learners focus on logical analysis and thinking as ways to tackle the problems [15].

8. Influences of Coloured Picture in the Textbook
According to J. Dunlosky et al. [16], most students often endorse the use of rereading and highlighting for study. These two ineffective methods are found to have low utility besides not able to retain
knowledge for a longer period. Nevertheless, some of the students that applied the practice testing methods appear to gain benefit from its use. Those students show better performance on a final exam. Following this matter, it is believed students that are being left behind by an educational system are in crisis which then makes them not fully understand what they have learned. It is even worse when the country will not be able to produce quality engineers in the future.

There are five techniques according to [16], that are considered as a low utility assessment; i. The summarization, ii. The highlighting, iii. The keyword mnemonic, iv. The imagery uses for text learning and v. The rereading. These techniques may find useful in a certain time but still not provide full benefits and ineffective. Therefore, improving the teaching and learning methods are very crucial for both teachers and students.

Nowadays, textbooks are still considered as an important resource in the education system. The way how the information is delivered is very crucial to grab students’ attention. One of the best ways is by adding images with attractive color in into the textbooks. Certain colors have their own impact on memory that can be applied in learning process. Figure 4 shows six types of colors with their impact to memory [17].

![Figure 4: Colors Impact on Memory](image)

Referring to Figure 4, it can be concluded that by using different colors to different topics will improve the availability to recall the topic at any time. However, the evaluation more focuses on the content rather than the study of the impact of pictures in the textbooks [18]. It is good to note that, pictures capable in encourage students to study the related text and increases their attention to detailed processing of textual data that is included in illustrations. Moreover, they can explain the content that hard to understand and thus increase recovery potential for the picture text content. Sara K. et al. [18] suggested that there are three elements that make up the quality of the textbook which included; i. Persuade the use of technology, ii. Suitability and iii. Environment. These elements are the things that the author should be aware of to motivate students in their studies. Therefore, it is to avoid students become boring even the book is incredibly inspiring and informative.

9. QR Code Feature
Quick Response (QR) code is a 2D barcodes consists of black modules that are arranged in a square pattern on a white background. It is developed in 1994 by Denso – Wave which is a Japanese automatic data capture equipment company for the Toyota motor corporation [19]. It is created as an alternative to the barcodes system [20] and initially used to track the vehicles at the time manufacturing [21].
According to Deepashree M. et al. [21], people become more interested to use the QR code system because it is easy to generate, fast reading, and able to load a lot of information in many forms. For instance, information such as the website URL link, contact information, video streaming and plain text [22]. Figure 5 shows the structure and components in QR code [23].

![Figure 5: Structure and Components of QR code](image)

As shown in Figure 5, there are three patterns on the QR code which are finder patterns, timing patterns and alignment patterns. The finder patterns are used to detect position, size and inclination of the QR code. As for timing patterns, it acts as an identifier for the central co-ordinate of data cell whenever the QR code is distorted. Next, the alignment used as a correction pattern that corrects the distorted data while the quiet zone is a margin space that is crucial for reading the QR code [5].

It is known that the features in QR code mostly reflect the positive feedback towards the users. Therefore, Deepashree M. et al. [21] mentioned that the QR code exhibits the potential to apply in education system. The use of QR code in the education can be categorized in the context of mobile learning [24]. Thus, it is considered as one of the effective medium of learning since the most used device in the world is the mobile smart phone [25]. Figure 6 shows the process on how does the QR code work on smart phone [26].

![Figure 6: QR Code Recognition Process](image)
Based on Figure 6, the QR code recognition process starts when the smartphone scans the code. After that, the code will be decoded by the software on the smartphone and converted into a string of characters. The commands on the characters determine the type of information that appear, for example, web page, location verification as well as access to video link or any other information at rapid rate. Following this matter, it can be said that the use of QR code in mobile learning is very effective and easy to apply. Apart from that, teachers will become more creative in performing the learning session with the student to blend with the development of the technology. For example, by applying the QR code, it capable in draw the attention of the students allowing them to learn effectively. Next, Rikala J. et al. [24] from her research stated the use of QR code able to expand the learning experience and provide the genuine tasks that take place in real-world settings. Furthermore, the QR code can be accessed all over the areas as long as the users are in the internet coverage area and equipped the mobile phones with a QR code scanner.

10. The Implication of Video Learning Among Students
Following today’s educational trend, teaching material based on video clips is seen to have at least as equally efficient as standard teaching lectures. Panagiota N. et al. [27] explained in his paper that by using video as a learning medium, it shows more effective effects rather than text. Consequently, it enhances the student’s satisfaction and motivation during the learning process. Apart from that, video learning is flexible because it can pause or skip throughout the video and able to access in particular areas.

Emily C. [28] mentioned that the ability to communicate with viewers’ emotions is one of the greatest strengths of video. Due to this ability, the video may have a strong positive effect to develop the motivation and effective learning. J.M. Marshall [29] clarified that people will generally remember according to the; 10% of what they read, 20% of what they hear, 30% of what they see and 50% of what they hear and see.

Guo et al. [30] analyzed that the duration time of the streaming video affects student engagement. As the streaming videos lengthened, student engagement is dropped off and decreased. The maximum median engagement time is lasts within six minutes of video length. Otherwise, it will be likely wasted effort for making videos longer than six to nine minutes. Therefore, it is recommended to create two or more videos depending on the content for the topics that require long explanation. As for that, Cynthia J. B. et al. [31] suggested four characteristics to attract students which can be applied in video learning are; i. Conversational style, ii. Speak relatively fast with passion, iii. Ensure that the materials are for students in this class and iv. Match modality.

Throughout students’ participation in video learning, they can improve their understanding of the subject. Apart from that, the video learning also supports the active learning that enhances the students’ performance. N. Sasikumar [32] listed that, the involvement of students more than passive listening, engagement in activities and increase motivation to study are the major characteristics that related to active learning strategies.

11. Conclusion
The development of electrical engineering learning kit will potentially benefit to the society considering that it able to enhances the positive attitudes among the students in the teaching and learning process especially in STEM education. Besides that, the learning kit can be used as a reference for individuals who want to strengthen their understanding through the basic concepts in electrical engineering field. Apart from that, the actual target of this learning kit is students from primary and secondary grades. However, it can be useful for lecturers and technicians who involved in the electrical engineering field as well as students in the higher education institutions as it includes the basic concepts in electrical engineering which are compulsory subjects to be taken at early year of the study.
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