

# Application of Systematically Designed Learning Module to Enhance Engagement, Comprehension and Skills in STEM Education

Mohd Farriz Basar<sup>1\*</sup>, Izzatie Akmal Zulkarnain<sup>1</sup>, Nur Irrina Balqis Mohd Farriz<sup>1</sup>, Norhaslinda Hasim<sup>1</sup>, Kamaruzzaman Sopian<sup>2</sup>

<sup>1</sup>Faculty of Electrical Technology and Engineering, Universiti Teknikal Malaysia Melaka (UTeM), Hang Tuah Jaya, Melaka, Malaysia,

<sup>2</sup>Department of Mechanical Engineering, Universiti Teknologi PETRONAS (UTP), Perak Darul Ridzuan, Malaysia.

\*Corresponding Author's Email: mfarriz@utem.edu.my

## Abstract

In STEM (science, technology, engineering, and mathematics) education, learning modules are crucial tools. However, some of the existing resources lack empirical validation, have poor design, and have limited contextual applicability. These drawbacks hinder their capacity to gain useful skills, form deep relationships, and advance their intellectual knowledge. To address these problems, this research develops and meticulously evaluates a well-designed learning module for students in elementary and middle school. Increasing awareness and enthusiasm in STEM disciplines is the aim. Comprehensive experimental procedures, full-color images, equipment lists, and succinct theoretical explanations are all included in this module. It contains instructional resources that use QR codes to enhance interactivity and learning effectiveness. Students and professors were among the 194 participants who filled out a thorough survey. A statistical test and a scoring system based on rubric were used to analyze the responses. The figures show that the majority of respondents agree, putting their overall viability at 4.23 out of 5, or "very high." In addition to having a greater capacity to apply engineering concepts in practical contexts, respondents reported notable gains in their knowledge, motivation, and involvement. These findings show how well thought out and empirically supported learning modules may significantly enhance conceptual understanding, develop practical skills, and raise student engagement, offering a repeatable basis for curricular innovation. This paper advances STEM pedagogy by demonstrating how research-informed module design might improve engineering education.

**Keywords:** Engineering Education, Learning Module Development, STEM Education, Student Engagement.

## Introduction

UNESCO's Sustainable Development Goals (SDGs), particularly SDG 4: Quality Education, are in accordance with the development of effective teaching strategies, such as comprehensive learning modules, according to the UN Department of Economic and Social Affairs (UNDESA) (1). Furthermore, according to the Inter-Agency and Expert Group on Sustainable Development Goal Indicators (IAEG-SDGs), by 2030, there must be a significant rise in the number of adults and youth with the technical skills necessary to assist people in finding employment and launching their own companies. It is seen as a significant global indicator as part of SDG 4 (2-4). Many still attend traditional schools, but graduates are now more responsible and need not just excellent technical skills but also professional and "soft" abilities due to the rapid advancement of technology (5, 6). These objectives are often not satisfied by lecture-

based approaches, particularly when discussing complex scientific and technical concepts (7, 8). A lot of the time, hands-on and experiential learning would help people understand concepts better (9-11). Without these kinds of methods, students often have trouble understanding basic concepts, which makes them less ready for the challenges facing society and business today. New ways of teaching and learning are needed to meet these needs, especially in engineering education. These new ways need to combine basic science, technical knowledge, professional practices, and soft skills (5, 7, 12). One popular method is STEM education, which stands for Science, Mathematics, Engineering, and Technology. It was first thought of by the National Science Foundation (NSF) (13, 14). A popular way to teach that combines these four subjects in a way that is based on real life is called STEM (14-17). Throughout history, STEM

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education, which stands for Science, Mathematics, Engineering, and Technology. It was first thought of by the National Science Foundation (NSF) (13, 14). A popular way to teach that combines these four subjects in a way that is based on real life is called STEM (14–17). Throughout history, STEM education has led to technological progress, such as the creation of cars, electric lights, and industrial machinery (13).

Even though STEM areas are vital, fewer students are interested in them now than in the past (18). While declining student interest in STEM has been reported internationally, this study focuses on trends observed within the Malaysian educational context. Confusing, unmotivating, and less engaging STEM learning experiences have resulted from an over-reliance on traditional, theory-based teaching techniques (9, 19). The ability of future generations to significantly advance science and technology is called into doubt by this decline. Furthermore, STEM education is less successful when there are no interesting and easily accessible learning materials available (1, 20, 21). Moreover, student enrolment in engineering programs has declined due to unengaging instructional content, unenthusiastic teaching practices, and inadequate foundational knowledge (22).

Despite efforts to improve STEM education, a significant problem remains there are no well-designed and proven learning modules that integrate theoretical knowledge with practical tasks in a manner that is both engaging and pedagogically sound (13, 14). Many existing instructional resources tend to oversimplify content or provide limited opportunities for meaningful hands-on application, resulting in minimal improvements in learning outcomes. While STEM approaches are increasingly adopted, current STEM curricula often remain theory-focused and lack systematically designed modules that align cognitive, psychomotor, and affective learning domains.

Within the broader STEM context, electrical engineering was selected as the focus of this study because it naturally supports the integration of theoretical concepts with hands-on learning activities. Fundamental topics such as basic circuits, energy flow, and system behavior are particularly suitable for practical experimentation, enabling students to actively engage with the learning process. These topics are also commonly

introduced at early educational stages and can be implemented using simple, safe, and low-cost experimental setups. As such, electrical engineering provides an appropriate and representative platform for demonstrating the effectiveness of a systematically designed and validated STEM learning module.

Unlike many existing STEM or engineering learning modules that are often used only as supplementary materials, the proposed module is designed as a complete instructional framework. It combines a systematic structure, alignment with cognitive, psychomotor, and affective learning domains, and empirical validation, while integrating step-by-step experiments, real-color images, QR-code-based multimedia resources, and outcome-based evaluation to actively support student understanding, skill development, and engagement.

To address the identified limitations, this study develops and validates a structured STEM learning module that integrates practical activities, multimedia support, and outcome-based evaluation to enhance student engagement and skill development. The current project aims to bridge the existing gap by designing and testing a comprehensive learning module for STEM and electrical engineering education. This research is organized as follows: Section 2 reviews the concept of STEM education, Section 3 details the essential components of the proposed module, and Section 4 presents student feedback and feasibility findings from the evaluation survey.

## Methodology

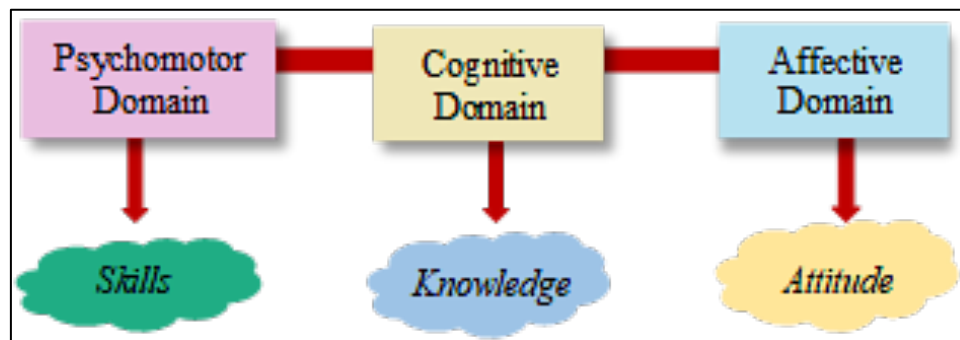
This study adopts a design-based research approach to guide the development of the STEM learning module. As shown in Figures 1 to 4, the methodology integrates systematic instructional design and formative evaluation through a structured sequence of introduction, implementation, and evaluation phases aligned with cognitive, psychomotor, and affective learning domains. This methodological approach is particularly suitable for learning module development, as learning modules function as structured instructional tools that directly shape the teaching and learning process.

Learning modules are vital tools in education, as they can significantly enhance the teaching and learning process (1, 21, 23). Traditionally, teachers

employ modules as instructional aids to support classroom activities and facilitate knowledge sharing among students. A comprehensive learning module offers additional benefits by increasing student interest in STEM subjects and reducing misconceptions during the learning process. Its primary purpose is to help students master fundamental concepts systematically and effectively (20, 24).

### Domains of Learning

As shown in Figure 1, a successful learning module should include the three basic learning domains: emotional (attitudes), psychomotor (skills), and cognitive (knowledge) (25). There are three domains that must be considered while creating learning assignments to guarantee comprehensive student growth (23). By combining these areas, classroom instruction is reinforced, creativity is encouraged, and long-term memory retention is improved.



**Figure 1:** Integration of the Three Learning Domains

The cognitive domain focuses on knowledge and thought processes (25). In this module, each experiment or topic is presented with theoretical explanations supported by diagrams and full-color illustrations. Visual elements are intentionally included, as certain colors can stimulate memory and improve recall of previously learned material (26–28).

Practical skills and experiential learning are prioritized in the psychomotor domain. In science and electrical engineering, experimental exercises are very useful for enhancing understanding (29, 30). Students may see project demonstration films at any time and from any location thanks to the interactive features, including QR codes, that are included in this module. By showing the results, highlighting best practices, and assisting students in project preparation, these movies increase student involvement (28, 31).

Attitudes, emotions, and values are all part of the affective domain in the learning process (30). Innovative methods of delivery, such as video learning, visual materials, and hands-on experiments (32), are employed to foster positive affective responses, including motivation, enthusiasm, and appreciation (33–35). The participation of students in activities that necessitate movement and collaboration not only improves comprehension but also offers a

memorable and comprehensive learning experience (23).

### Essential Components

To assist instructors and students in navigating the whole learning process, a comprehensive learning module must be systematically arranged. Twelve key components are proposed to do this, ensuring that each stage of a topic or project is delivered in an intelligible, engaging, and effective way. The introduction, execution, and conclusion are the three stages into which these elements are organized. As shown in Figure 2, the introduction phase is an essential first step in every experiential learning activity since it not only sets the necessary context but also sparks students' curiosity. This may be achieved by systematically combining many instructional elements.

Engaging students and assisting them in placing the exercise in context requires a succinct but comprehensive title and supporting picture. Second, pupils are better able to connect abstract ideas to real-world situations when a symbol that represents the project's subject is used. Giving students a QR code that would make it simple for them to access more digital resources, including interactive simulations, video demonstrations, or reference materials, is the third alternative. This will help them learn outside of school. Giving an anticipated project cost helps people understand

how useful and practical it will be in the real world (36). A clear time frame makes it simpler to plan and plan lessons. To aid students learn, there should be a short summary of the project's goals and scope. A detailed list of all the necessary equipment, together with pictures of each item, makes the tasks clearer, reduces the chance of confusion, and makes it easier to do the same exercise in different courses or labs. Together, these parts help students get involved at first and create a structured framework that encourages continuing questioning and participation throughout the learning process.

Figure 3 illustrates that the implementation stage is the most important part of the learning process since it focuses on students being directly involved in the activity. To make this phase as effective as possible for learning, it should include two important parts. The first step in explaining the procedures should be to use brief, straightforward,

and understandable language. This will ensure that students from all backgrounds can follow the instructions without any issues or misunderstanding. Cognitive overload is less likely to occur when instructions are straightforward and easy to grasp (27), which promotes self-directed learning and increases confidence. Second, there is a lot of visual help created by using actual color photos in the process phases (26, 28). Through their ability to link textual explanations with practical applications, these images enhance courses and facilitate more accurate work completion. It has been shown that integrating multimodal teaching techniques that include text, graphics, and experiential activities improve conceptual comprehension, procedural accuracy, and long-term information retention (13, 26). These components taken together are consistent with best practices in STEM education.

## 1.1 Simple Torchlight





QR Code



**Project Cost**  
RM 4.00



**5 minutes**

**Short Description**

Simple Torchlight is a straightforward project that demonstrates a basic electrical circuit. By using simple components, a simple and practical torchlight can be made. The LED is a semiconductor that emits light when an electric current passed through it.

**Apparatus**

- (a) 2 Bottle caps
- (b) 3 LEDs
- (c) 1 Battery 9V
- (d) 1 Battery snap 9V
- (e) PVC tape



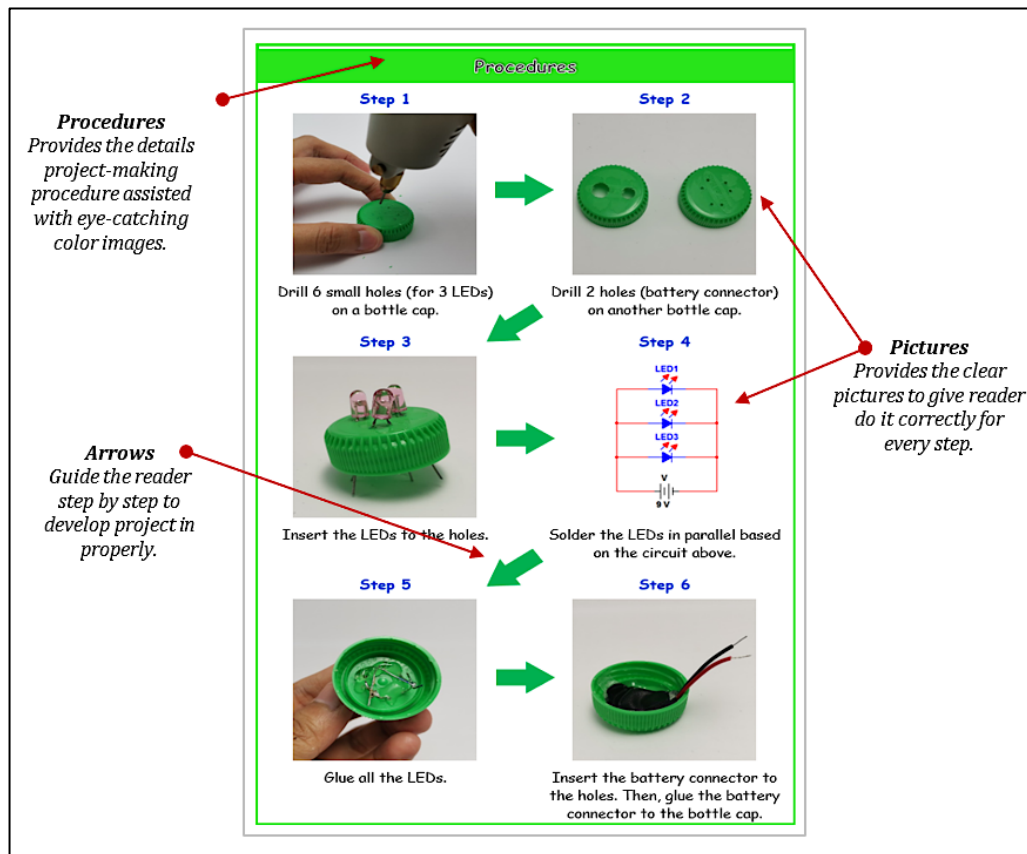
**Figure 2:** Essential Information for the Initial Stage of the Project

The last step is crucial for integrating the information and abilities acquired during the activity, as shown in Figure 4. Two crucial elements intended to improve the relationship

between theory and practice are included in this phase. To ensure that students not only copy methods but also get a conceptual knowledge of the mechanics driving the project, it is necessary to

first deliver a succinct yet technically sound explanation of the underlying scientific and engineering ideas. Such justifications facilitate the development of higher-order thinking and transferable abilities by bridging the gap between disciplinary knowledge and experiential learning (9, 26). Second, when clearly defined learning

outcomes are articulated, both students and teachers may assess how well the intended goals have been met. These results provide a clear standard for evaluation, direct reflective practice, and motivate students to review their own development critically (7, 13).



**Figure 3:** Important Information for the Project's Middle Section


Collectively, this stage completes the twelve-component framework that underpins an effective learning module. In addition to enhancing procedural accuracy and comprehension, the framework promotes engagement, creativity, and reflective learning via the use of outcome-based evaluation, digital integration, visual reinforcement, and clear procedural guidance. In this way, it promotes STEM education best practices, where it is widely accepted that integrating structured instruction, multimodal resources, and unambiguous assessment standards is essential to fostering both immediate learning gains and long-term intellectual growth (13, 27).

### Designing Easy-to-Follow Procedures

Procedures in a learning module must be organized, clear, and succinct in order to guide students through the desired activity. Apart from

being a useful teaching tool and a pedagogical scaffold, a well-designed strategy provides useful direction and supports learning objectives (9, 37). Any ambiguity regarding the experimental requirements may be resolved by employing clear, concise language and providing a rational explanation of the steps involved in the approach. In addition to facilitating the confident completion of experimental objectives by students, clearly defined procedures also promote self-regulated learning and independence, thereby increasing the probability of learner success (7, 38). Furthermore, the link between theoretical knowledge and the development of practical abilities is strengthened, and repeatability is improved by the clarity of procedural design, which facilitates the accurate replication of experiments (13, 39).


The Book With No Formulas
Topic 3; Magnet



**Now, let's discuss the technical behind the project.**

It is not logic when a material is not going down following the gravity. But it is true when involve with magnet. In this project, the magnet is floating in the air because of magnetic fields.

**Technical Explanation**  
*Explain in detail the technical description to clarify the basic electrical concepts applied to the project.*



**What I have learns from this project?**

1. Magnets able to attract or repel depends to the poles.
2. A north pole of magnet will attract to a south pole of magnet.
3. A north pole of magnet will repel with a north pole of earth.
4. A south pole of magnet will repel with a south pole of earth.

**Learning Outcomes**  
*State the things that are learned through the project.*

**Figure 4:** Required Details for the Project's Final Section

By providing a multimodal teaching aid, the utilization of real-color images further improves procedural effectiveness. By integrating verbal (text) and non-verbal (picture) representations, dual coding theory seeks to enhance long-term memory and promote deeper information storage (26, 40). According to the cognitive load hypothesis, if students get both clear verbal instructions and visual assistance, they may devote more cognitive resources to meaningful learning (27). Clear language and pertinent illustrations work together to reduce misunderstandings and enhance overall performance, procedural accuracy, and student involvement (28). The implementation strategy and corresponding learning outcomes associated with these design principles are summarized in Table 1. When coupled, these design principles ensure that procedures are not only operational instructions but rather an integral part of the instructional approach. They provide pupils the confidence and

structure they need to succeed on experimental projects, promote comprehension, and encourage active involvement.

Both students and teachers benefit from the effectiveness and efficiency of teaching and learning when they use engaging and well-structured instructional materials, since they significantly improve students' cognitive processing (26, 37, 38). A crucial factor in grabbing and holding learners' attention is the delivery method, which is equally important (31). Colorful picture integration into educational materials is one evidence-based approach (40, 41). Specific color schemes have been shown to influence memory retention via empirical research, acting as cognitive signals that make knowledge acquisition and retrieval easier (26, 27). Figure 5 shows how six different color groups have varying impacts on memory function, highlighting the educational benefits of thoughtful visual design.

**Table 1:** Implementation and Assessment of Easy-to-Follow Procedures

Items	Descriptions
Idea	Students can successfully complete the experiment by following the step-by-step procedures supported with real-color images.
Implementation	Prior to the experiment session, the instructor performs and records the entire process. This documented procedure is then provided as a reference for students.
Evaluation and Outcome	Following the guidelines helps students carry out the experiment precisely while reducing mistakes like using the wrong materials or not being ready during the development phase.

<b>Red</b>	<b>Yellow</b>	<b>Orange</b>
Instantly grabs your attention and stimulates the brain ideal for memory retrieval	Attention grabbing colour, hues of yellow help to stimulate mental activity	Prevents boredom and keeps the mind focused
<b>Blue</b>	<b>Purple</b>	<b>Green</b>
Calming influence and is known to increase concentration proven to boost creative thinking	Calms whilst helping to release creativity and helps you to express ideas more easily	Cooling for the eyes, green helps with concentration and balances the mind.

**Figure 5:** Influence of Colors on Memory Retention

The combination of real-time, contextually appropriate pictures into procedural information improves experimental accuracy by reducing the risk of operational errors. With the help of this visual reinforcement, students may properly recognise, choose, and use the right components and resources, ensuring consistency and dependability throughout the project's growth (42, 43). This method conceptually aligns with dual coding theory, which states that verbal information is improved when combined with appropriate visual representations (44). The coherence and contiguity principles, which imply that meaningful learning is promoted and unnecessary cognitive load is decreased when text and visuals are skilfully linked, are more significant since they include Mayer's multimedia learning notions (26). By making it easier for pupils to follow instructions precisely and developing a deeper comprehension of the material, clear written instructions and well-structured drawings are used to train students. The need for multimodal instructional design in STEM education is shown by these tactics taken together. Well-established theories of cognitive

and multimedia learning are in line with structured text, color cues, and real-time visuals. Improved learning outcomes and long-term information retention are the effects of these elements, which also promote understanding, procedural correctness, and engagement (13, 14, 39, 45).

### Integration of Video Clips

The effectiveness of video-based learning materials is becoming more widely acknowledged, if not more so than that of conventional lecture-based approaches. This aligns with current teaching approaches. In general, video learning is more successful than text-only methods because it improves students' understanding while also boosting their motivation and the general pleasure of the learning process (31, 39, 45–47). Video learning's intrinsic flexibility is a big plus; students may stop, fast-forward, or skip parts as needed, which encourages self-paced learning and customised engagement (28). Table 2 provides a summary of the use and assessment of video segments in the complete learning module of this study.

**Table 2:** Implementation and Assessment of Video Clips

Items	Descriptions
Idea	Prior to class, the instructor prepares video tutorials that demonstrate the step-by-step development of projects. These videos serve as continuous reference materials, guiding students until project completion.
Implementation	Each project is linked to a unique QR code, allowing students to conveniently access the instructional videos. This feature facilitates flexible self-learning, enabling students to engage with the material both at home and in other environments outside the classroom.
Evaluation and Outcome	Video-based learning improves students' understanding by promoting engagement with the material. Active learning techniques, such viewing films and putting what has been studied into practice, promote engagement, increase zeal, and enhance academic performance in contrast to passive listening.

Recent research indicates that individuals tend to retain 10% of what they read, 20% of what they hear, 30% of what they see, and as much as 50% of what they hear and see at the same time (27, 40). This emphasizes how crucial multimodal learning is. This illustrates how dual coding is promoted and unnecessary mental effort is reduced via the cognitive advantages of video teaching. The following best practices are exemplified by video clips in Mayer's multimedia learning principles, the contiguity principle, which highlights the need to integrate words and images to improve knowledge assimilation; the redundancy principle, which warns against confusing learners with identical on-screen text and narration; and the modality principle, which maintains that auditory explanations together with visuals improve comprehension more than text alone (26). Additionally, one of the most important advantages of video as a medium is its capacity to emotionally connect with students, which raises intrinsic motivation and facilitates deeper cognitive processing (28, 31, 48).

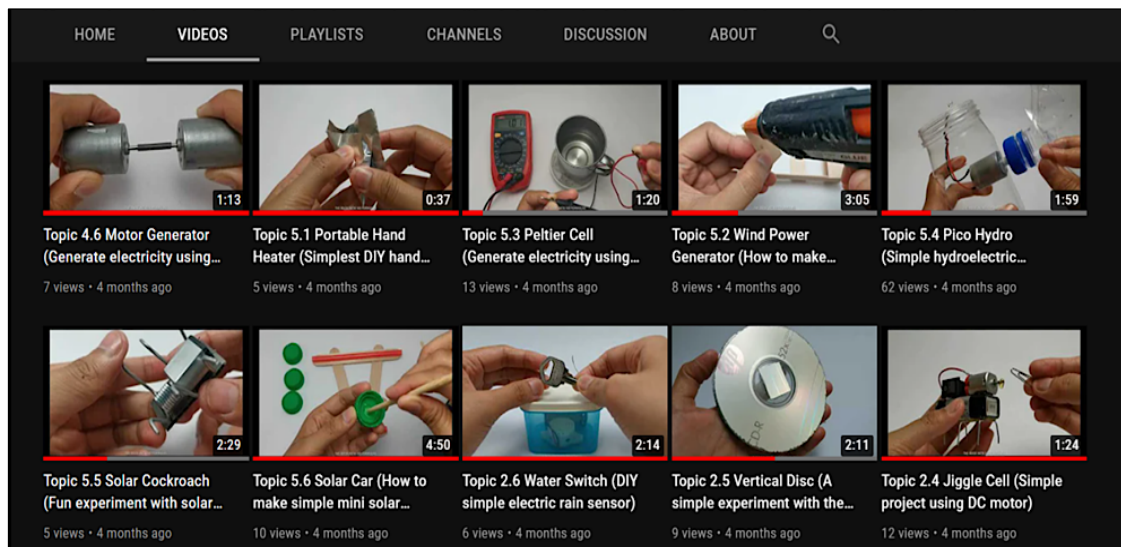
Figure 6 shows a selection of YouTube instructional films that are relevant to the planned learning modules. Each video provides comprehensive instructions by outlining the project's title, necessary supplies, procedures, and intended results. Together, these factors show how well video learning may be used as a teaching tool to improve procedural accuracy, conceptual comprehension, and the general calibre of STEM education for students.

A conversational delivery style that fosters a sense of social presence, passionate yet measured speech that conveys enthusiasm without overwhelming learners, carefully planned instructional materials

that ensure clarity and structure, and appropriate modality alignment so that verbal and visual inputs complement rather than conflict with one another are the four essential characteristics of effective instructional videos that consistently boost student attention and engagement (28, 43). When combined, these attributes help students concentrate better, stay motivated, and encourage deeper learning (49).

According to research, a video's duration has a significant impact on viewer engagement. The median viewing time has been observed to peak within the first six minutes and then decline significantly, particularly for videos longer than nine minutes (31). This is crucial to lesson planning since long, continuous video lectures cannot keep students interested or encourage active learning. Shorter films that focus on distinct learning goals are recommended. This approach aligns with Mayer's seven-segment theory (26), which posits that breaking down difficult material into manageable chunks improves student understanding (50).

Video production may be enhanced using additional multimedia learning techniques, such as segmentation. Videos should only include content that is relevant to the subject matter, according to the coherence principle. People may avoid consuming too much information at once thanks to this. To improve knowledge integration, the signaling notion emphasizes how crucial it is to use indications like arrows, highlights, or descriptions to direct learners' attention to crucial components. The segmentation concept and design tactics ensure that films fulfil both entertainment and educational functions (26, 27).



**Figure 6:** Share Project Videos on Social Media Sites

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While short films are simpler for people to watch and participate in, STEM laboratories usually need lengthier presentations that are difficult to interrupt without disturbing the flow. A balanced strategy is required in these situations. Chapter markers, interactive stop sections, or brief graphic explanations may all be beneficial for lengthy films. The cognitive advantages of signaling, coherence, and segmentation are combined with the need for thorough experimental validation in this hybrid strategy. This provides both excellent training and practical laboratory practice (39, 45, 48, 51).

### Integration of QR Codes

A two-dimensional barcode consisting of black squares set on a white backdrop is called a Quick Response (QR) code. It was first used by the Toyota Motor Corporation to monitor automobiles throughout the production process and was created in 1994 by Denso-Wave, a Japanese firm that specialized in autonomous data collection technology (52). QR codes brought about several

noteworthy advancements over conventional barcodes, such as easier fabrication, quicker reading, and the ability to store a much greater quantity of data in various forms. Because of these benefits, they were quickly adopted in a variety of businesses and, more recently, in educational settings. QR codes are often regarded as adaptable tools in contemporary education that facilitate the connection of digital and physical learning materials. With the ability to store text, photographs, video clips, online links, and contact information, they provide students with instant access to supplementary content via their mobile devices (52, 53). With information available "anytime and anywhere," this quick access reflects the ideas of mobile and ubiquitous learning, which promote flexible study and increased learner autonomy.

QR code also encourages just-in-time learning by allowing students to access content whenever they need it, enhancing contextual application and understanding (54). In the learning module developed for this study, QR codes operate as helpful links between textual text and interactive multimedia materials. When integrated with experimental activities or procedural instructions, they facilitate the smooth transition between digital and physical media by giving students instant access to films, detailed examples, or other references (53). Table 3 illustrates how QR codes were used and evaluated in this study. It also shows how they may enhance accessibility, interactivity, and engagement in STEM education while fostering a more technologically sophisticated and learner-centered environment.

**Table 3:** Implementation and Assessment of QR Codes

Items	Descriptions
Idea	Students access the instructional video through a designated QR code.
Implementation	The QR code is included in the students' activity book, which can be scanned using a smartphone for immediate access.
Evaluation and Outcome	For mobile learning, QR codes are a useful and intuitive tool. In addition to making access simpler, their integration encourages teachers to use more creative teaching strategies that complement modern technology. By using QR codes, instructors may pique students' attention and improve the learning process, making it more dynamic, effective, and engaging.

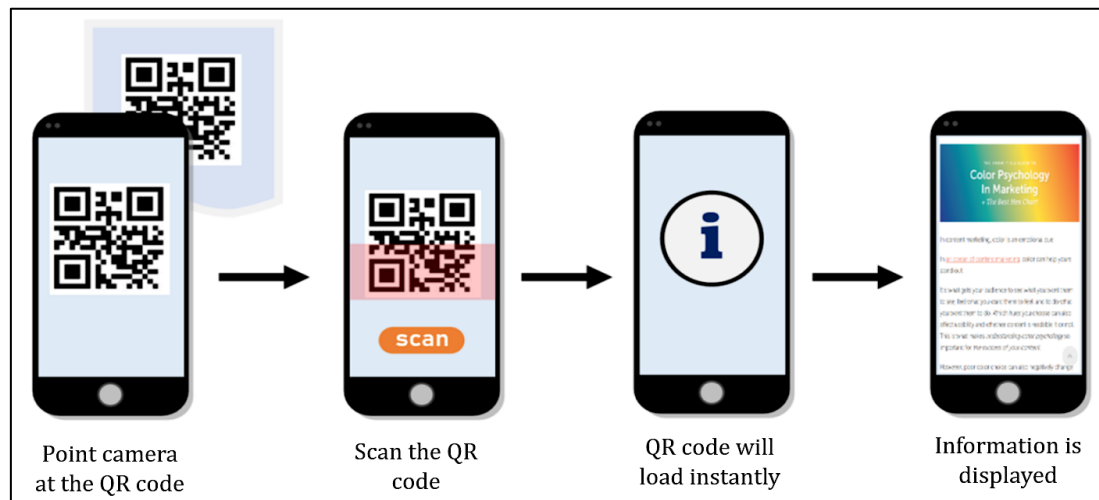
Through the integration of real-world difficulties with instructional information, the use of QR codes in educational contexts has the potential to significantly improve learning. Wherever there is internet access and mobile devices with scanners, QR codes are common. They are hence a flexible and favoured learning approach (55, 56). This mobility is directly linked to the concepts of mobile learning, which is seen to be one of the best study strategies in the digital age, especially given how common smartphones are around the world. Additionally, QR codes align with the principles of contextual learning theory and traditional learning, which both highlight the need of involving students in activities that replicate real-world situations (57). Through the application of knowledge, QR codes help pupils make the link between abstract ideas and real-world situations. This makes the material more useful and memorable (54). When a smartphone scans a QR code, identification of the code begins, as seen in Figure 7. The encoded data is then decoded and transformed into a character string by the device's software. This string tells the gadget what kind of content to show. The QR code may instantly provide material to students by directing them to a website, providing location-specific information, or streaming an instructional video. Students may immediately access necessary materials because to this feature's immediacy, which enhances instructional strategies and encourages just-in-time learning. Through the use of QR codes, classroom learning may be successfully linked to real-world activities, promoting interactive and context-based engagement. Students often learn more efficiently, are more motivated, and exhibit

better information transfer as a consequence (58, 59).

### Technical Explanation

Despite the increasing adoption of digital technologies in education, activity books and textbooks continue to serve as indispensable components of the learning ecosystem. These resources frequently provide the theoretical foundations of experiments, offering students readily accessible reference material to support their practical work. Following the completion of hands-on activities, students can revisit these theoretical explanations to consolidate their understanding and strengthen the connection between abstract concepts and experimental outcomes (21, 60).

It is crucial to comprehend the methods used to teach pupils technical knowledge. In order to keep students' interest and guarantee that they understand the important concepts, the information has to be easily comprehensible and rationally structured (7, 61). Accordingly, the learning module's organised technical explanations help students understand every stage of the process and serve as a resource for them when they use what they've learnt in the real world. This method is a good example of the scaffolding concept in education, which says that students should be guided gradually via simple, sequential explanations that allow them to build on what they already know (62). Additionally, the module eliminates unnecessary mental effort by providing information in a concise, well-organized manner, which is consistent with cognitive load theory (27). This helps students relate what they learn in class with what they do in the real world.



**Figure 7:** QR Code Scanning and Decoding Process

Table 4 shows how these parts of the technical explanation were used and tested in the last phase of the project. Together, they provide a unified framework that connects theoretical knowledge

with practical use, which helps people comprehend things better, remember them longer, and learn skills that can be used in other areas (63).

**Table 4:** Implementation and Assessment of Technical Explanatory Elements

Items	Descriptions
Idea	Students can link theoretical concepts with practical applications and experimental results.
Implementation	The learning module provides a comprehensive technical explanation that clarifies the principles underpinning each experiment.
Evaluation and Outcome	The section entitled “ <i>Technical Background of the Experiments</i> ” explains the fundamental concepts in a clear and engaging manner. It presents the material in an organised way that helps students grasp complex ideas more easily and supports instructors in guiding effective learning experiences.

Many students continue to depend on rereading as a primary method to study, but this method fails to aid them learn in the long term and primarily only gives them a shallow comprehension of the material. These kinds of restrictions can make it hard for students to keep up with the demands of STEM disciplines, where understanding things on a deeper level and being able to use what they learn are important (64). It is not too complicated to add more effective study and teaching approaches, such as active recall and spaced repetition, into daily life. Active recall helps students learn by making them remember formulas, concepts, or processes for solving problems, while spaced repetition helps them master the information by going over it repeatedly at longer intervals. In reality, STEM teachers can use these methods by giving brief exams at the beginning or conclusion of classes, giving students digital flashcards for key ideas, or planning regular reviews of problem sets that have already been taught. These methods not only help students remember what they've learned, but they also help

them feel more confident about using what they've learned to solve new and difficult issues (65).

## Results and Discussion

To assess the effectiveness and practicality of the proposed learning module, a student survey was carried out using an approach adapted from previous research (66). The survey, which comprised ten questions, was distributed through Google Classroom to ensure that all participants could access it easily and without logistical difficulties.

The survey had both rating-scale and dichotomous questions, enabling students to provide both explicit answers and more nuanced viewpoints on the twelve main module components listed in Section 2. In addition, affective outcomes such as student motivation, engagement, and enthusiasm were quantitatively measured using Likert-scale items based on students' perceptions after the module implementation.

To better understand how the module was seen in terms of its overall success, the research collected direct input from students. This allowed it to

identify both the module's strengths and areas that would need further work. A substantial amount of data for analysis was provided by the 194 students who participated in total. A five-point Likert scale (1 = Very Low, 2 = Low, 3 = Average, 4 = High, and 5 = Very High) was used to analyse the responses, enabling a systematic interpretation of students' perceptions. In this study, mean scores were interpreted using predefined threshold ranges commonly applied in five-point Likert-scale analysis. Mean values between 3.50 and 4.49 were classified as "High", while values between 4.50 and 5.00 were classified as "Very High" (67).

As summed up in Table 5, the results indicate that the module is generally seen to be practical and useful for STEM teaching; nevertheless, the feedback also identifies areas that require development, especially in terms of matching specific components with a variety of 10 learning needs. These observations highlight the significance of iterative development, where continuous assessment and improvement are necessary to guarantee that such modules attain both practical relevance and pedagogical effect.

**Table 5: Implementation and Assessment of Technical Explanatory Elements**

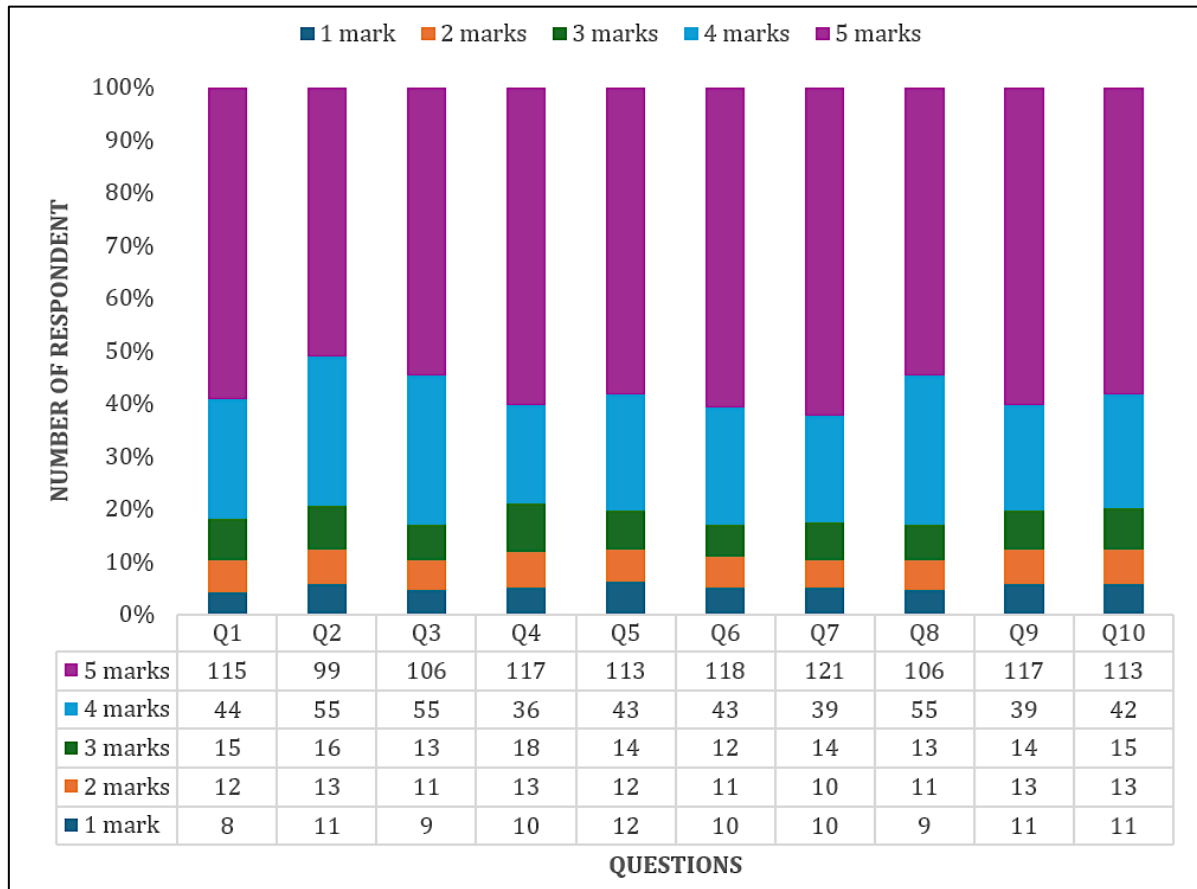
No.	Evaluation aspect	Average	Feasibility
Q1	Usage of simple and clear language	4.27	Very High
Q2	Educational (material content)	4.12	High
Q3	Display (coloring, images, animation)	4.23	Very High
Q4	Ease of material structure	4.22	Very High
Q5	Learning module enhances new understanding and ease of learning	4.20	High
Q6	It is easy to understand the engineering concept help to apply to the others project.	4.28	Very High
Q7	This learning module can increase readers interest and motivation in STEM education	4.29	Very High
Q8	This learning module can be used any time	4.23	Very High
Q9	Readers feel that the comprehensive module is fun to learn.	4.23	Very High
Q10	Readers feel that the module enhances knowledge and practice competencies.	4.20	High

The assessment survey's results, which assessed the comprehensive learning module in 10 important areas, are shown in Table 5. An average feasibility rating scale from "High" to "Very High" was used in the investigation. The results clearly support the usefulness, efficacy, and influence of the module on STEM education. Q7 had the highest score, suggesting that the module successfully raised students' enthusiasm and interest in STEM fields. It is evident that the module was a great success. It was praised for its ability to simplify difficult, technical subjects so that they may be easily understood and used in everyday situations (Q6). In a similar vein, pupils were able to follow along without becoming lost since the material was presented rationally (Q1, Q4). People really valued how colors, pictures, and brief animations (Q3) made learning seem livelier and captivating, therefore the use of visuals was a huge success. With students admitting that the software was versatile, accessible, and generally easy to use, this positive pattern persisted (Q8 and Q9).

Although Q2, Q5, and Q10 scored somewhat lower, the results nevertheless indicate that participants valued the module's instructional content, ease of use, and its ability to support skill development. The module received strong endorsement from both students and instructors, as reflected by an overall average rating of 4.3 out of 5. As shown in Figure 8, 80.4% of students reported that the learning process was interesting and enjoyable, 79.9% indicated improved understanding and application of engineering concepts, 88.9% expressed increased motivation and interest in STEM, and 83.0% acknowledged measurable improvements in knowledge and practical skills. Analysis of the percentage distribution reveals a consistent pattern across the evaluated indicators. Higher percentages were associated with indicators related to procedural clarity and visual support, suggesting that these elements were particularly effective in facilitating learning. In contrast, relatively lower percentages for certain indicators highlight areas where further

refinement may be beneficial. Overall, the observed trends indicate that the module performs strongly in promoting structured learning and

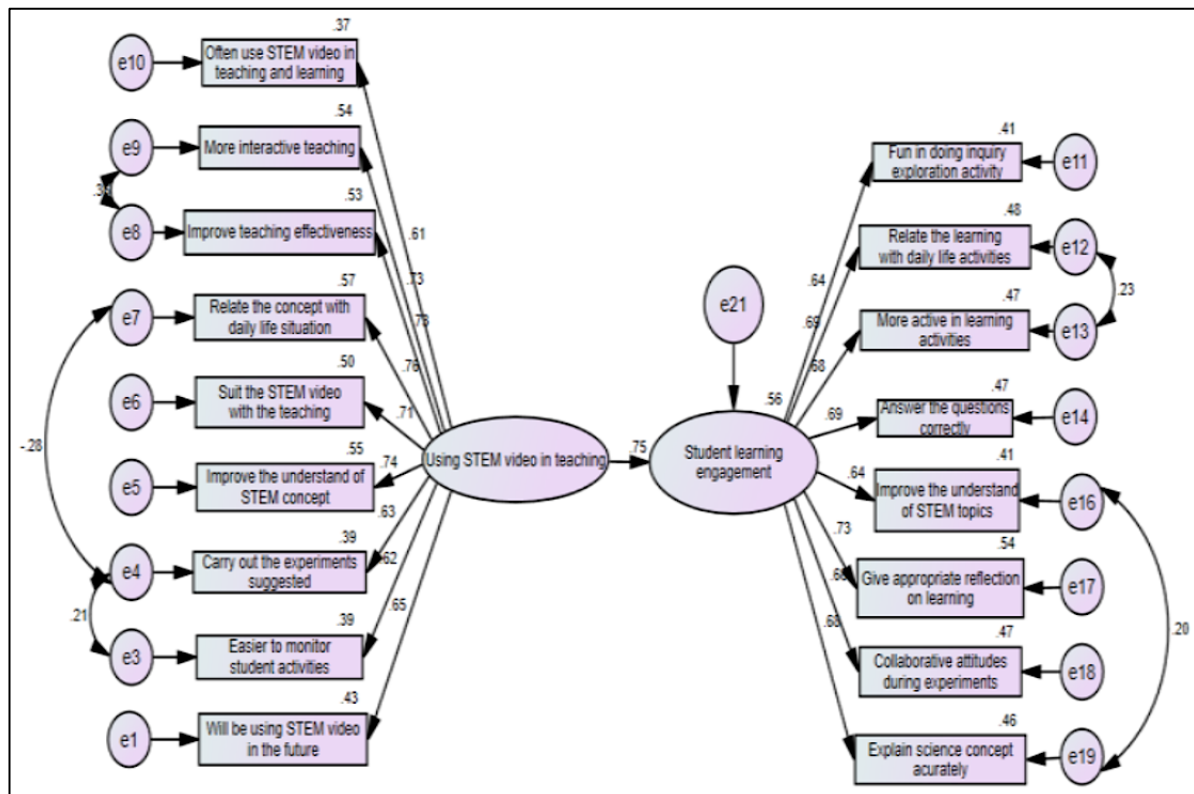
student engagement, while also identifying specific components that can be improved through iterative development.



**Figure 8:** Survey Feedback

A previous study examined how the use of STEM videos in teaching influences students’ learning engagement in Malaysia (68). Using a quantitative survey approach, the researchers collected data from 367 STEM teachers and analysed the results through structural equation modelling (SEM) using Analysis of Moment Structures (AMOS). Their findings revealed a significant positive relationship between STEM video usage and student engagement ( $\beta = 0.75, p < .001$ ), indicating that increased use of instructional videos was

associated with higher levels of student participation. The highly significant p-value further confirms that this relationship was statistically robust rather than coincidental. Moreover, the interaction model presented in Figure 9 illustrates the direct influence of STEM video usage on student learning engagement. It suggests that the integration of video in teaching promotes more interactive instruction, improved conceptual understanding, and greater student participation in learning activities.



**Figure 9:** Interaction model of the study involving the use of STEM video in teaching (68)

In comparison, the current study recorded a high overall mean score of 4.23 for the proposed instructional module, indicating strong perceived effectiveness and engagement among students. While the previous study statistically confirmed the strength of the relationship between video usage and engagement, the current study provides complementary evidence at the instructional implementation level. Unlike the earlier research, which focused primarily on modelling the relationship, this study embeds video within a structured, QR-enabled, and multimodal learning framework. This integrated design may explain the consistently high engagement scores observed, as it aligns cognitive understanding with guided procedural practice and reflective learning. Within the Malaysian educational context, such structured integration may offer more sustained engagement compared to video-only instructional approaches.

## Conclusion

Many students continue to experience difficulties in developing sustained interest in STEM (science, technology, engineering, and mathematics). Instructional approaches are often fragmented, and limited access to appropriate learning resources may hinder students from understanding broader conceptual connections

and developing essential practical skills. As a result, engagement declines, and students struggle to translate theoretical knowledge into real-world application.

To address these challenges, this study developed and validated a structured learning module designed specifically for elementary and middle school students. The module simultaneously supports three learning domains: cognitive (conceptual understanding), psychomotor (hands-on application), and affective (motivation and interest). It incorporates concise theoretical explanations, comprehensive equipment lists, step-by-step procedural guidance, visual supports, and QR codes linking to interactive instructional videos. This integrated design enables students to work more independently, build confidence, and bridge the gap between theoretical knowledge and practical implementation.

Feedback from 194 students and instructors indicated a very high overall feasibility score (mean = 4.23 of 5). Additionally, 88.9% of respondents reported increased interest in STEM, 83.0% observed improvements in knowledge and practical skills, and 79.9% indicated a stronger ability to understand and apply engineering concepts in project-based tasks. These findings

demonstrate that a systematically designed and research-informed instructional module can significantly enhance student engagement, motivation, and skill development. Apart from that, this study contributes to STEM education literature by presenting an empirically validated, structured instructional framework.

This study highlights the importance of continuously developing, evaluating, and refining structured instructional strategies in STEM education. Nevertheless, the findings are limited to the current sample and subject focus. Future research should investigate long-term learning retention, compare the module with alternative teaching approaches, and evaluate its adaptability across different STEM disciplines. With broader implementation and empirical validation, such structured, learner-centered frameworks may contribute meaningfully to curriculum enhancement and evidence-based educational policy development.

### Abbreviations

STEM: Science, Technology, Engineering, And Mathematics, QR: Quick Response.

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### Author Contributions

Mohd Farriz Basar: conceptualisation, methodology, data analysis, writing, Izzatie Akmal Zulkarnain: conceptualisation, methodology, data analysis, writing, Nur Irrina Balqis Mohd Farriz: conceptualisation, methodology, data analysis, writing, Norhaslinda Hasim: conceptualisation, methodology, data analysis, writing, Kamaruzzaman Sopian: technical guidance, critical revision. All authors read and approved the final manuscript.

### Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

### Data Availability

The data used in this study are available from the corresponding author upon reasonable request, in line with ethical guidelines and confidentiality considerations.

### Declaration of Artificial Intelligence (AI) Assistance

The authors declare that generative AI and AI-assisted technologies were used solely to improve the clarity, grammar, and language of the manuscript. All concepts, instructional materials, learning activities, and interpretations presented in this manuscript are the original work of the authors.

### Ethics Approval

Not Applicable.

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