

# The Impact of Using an Augmented Reality e-Module for Introduction to Power Systems on Bachelor of Electronic Engineering Students at Universiti Tun Hussein Onn Malaysia

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DOI: <https://doi.org/10.30880/ritvet.2025.05.02.010>

## Article Information

Received: 21 July 2025

Accepted: 01 December 2025

Available online: 30 December 2025

## Keywords

Augmented Reality (AR), e-Module, Power Systems, Successive Approximation Method (SAM), Behaviorist Learning Theory, Students Academic Achievement

## Abstract

Augmented Reality (AR) is an interactive technology that overlays virtual elements onto the real environment in real time and has been recognized as a promising teaching aid in technical education. This study developed and evaluated a marker-based AR Power Systems e-Module as an Instructional Teaching Aid (ABBM) for the topic Introduction to Power Systems at Universiti Tun Hussein Onn Malaysia. The module was designed using the Successive Approximation Method (SAM) and grounded in behaviorist learning theory. A quasi-experimental design was conducted over four weeks involving 60 undergraduate Electronic Engineering students, divided into treatment (n=30) and control (n=30) groups. Research instruments included pre- and post-tests for academic achievement and a questionnaire on students' acceptance of the module in terms of design, content, and functionality. Findings revealed no significant difference in achievement between groups, likely due to the short exposure period and technical constraints. However, students' acceptance of the AR e-Module was very high. Overall, the AR e-Module shows strong potential as a dynamic ABBM in the digital-era TVET education landscape.

## 1. Introduction

In today's sophisticated digital era, Augmented Reality (AR) is increasingly applied in education as a technology that overlays digital elements onto the real world, creating immersive and interactive learning experiences. It has been shown to enhance the understanding of complex concepts (Yoon et al., 2017), stimulate student motivation, and provide more engaging learning experiences (Letchumanan et al., 2024). Despite these advantages, the use of AR in Technical and Vocational Education and Training (TVET), particularly in electronic engineering, remains limited. This study therefore investigates the impact of an AR-based e-Module for the Introduction to Power Systems course among Bachelor of Electronic Engineering students at Universiti Tun Hussein Onn Malaysia. The research seeks to evaluate its effectiveness in enhancing student achievement and to identify barriers to broader adoption in TVET education. Teaching abstract subjects like Power Systems in TVET remains challenging, as students often struggle with concepts such as energy transmission, system stability, and equipment operation. Traditional methods like textbooks and static diagrams do not fully support visualisation and system-level thinking, particularly among vocational learners who benefit from hands-on and visual approaches (Tuli et al., 2022; Jizhi, 2019).

Augmented Reality (AR) offers an alternative by combining real-world settings with virtual content, allowing students to interact with 3D simulations and system components in real time (Udaya Shankar et al., 2023; Soltani & Morice, 2020). AR has proven effective across various disciplines in enhancing engagement and conceptual clarity (Kazakou & Koutromanos, 2023; Algerafi et al., 2023). In TVET contexts, it has been successfully used to simulate skill-based training, reduce dependence on costly equipment, and overcome infrastructure limitations (Mystakidis et al., 2022; Chandrasekar, 2022). Specifically in Power Systems education, This study addresses that gap by developing and evaluating an AR-based e-Module for Introduction to Power Systems. Unlike prior work that mainly emphasized skill simulation, this module focuses on conceptual visualisation of energy flow, network operations, and component analysis (Roopa et al., 2020; M. H. Rashid et al., 2023). It also examines both learning outcomes and student acceptance, providing insights into the feasibility of AR as a dynamic instructional aid in TVET education (Susan Trinoviorar et al., 2024).

## 1.1 Problem Statement

Teaching the Power Systems subject within TVET programmes presents persistent challenges, particularly in helping students grasp abstract and complex technical concepts. Topics such as energy transmission, load flow, component interactions, and grid stability require strong system-level thinking and spatial reasoning, skills that many vocational learners are still developing. In conventional classroom settings, these topics are often taught using static notes, whiteboard sketches, or textual explanations, which may not be sufficient to foster deep understanding (Ewis et al., 2024).

Considering these issues, there is a growing need to explore technology-enhanced interventions that bridge the gap between theory and practice. AR, which overlays digital content onto physical environments, offers the potential to present complex system behavior in intuitive, interactive formats (Udaya Shankar et al., 2023). Despite its promise, AR remains underutilized in TVET due to constraints in infrastructure, content development, and instructional models tailored to technical subjects. This study was initiated to address the pedagogical limitations in Power Systems instruction by developing and evaluating an AR-based e-Module that supports student engagement and conceptual understanding through immersive learning experiences. This study was initiated to address these pedagogical limitations by developing and evaluating an AR-based e-Module aimed at improving conceptual understanding and student engagement in Power Systems. This study was conducted with three main objectives. First, it seeks to develop an Augmented Reality-based e-Module for the topic Introduction to Power Systems. Second, it aims to examine the effect of the AR-based e-Module on student performance by comparing outcomes between the treatment and control groups. Finally, the study intends to determine the level of student acceptance of the e-Module in terms of its design, content, and functionality. This study offers a targeted solution to address conceptual and practical learning gaps in Power Systems education for vocational engineering students. By integrating Augmented Reality into an interactive e-Module, it aims to enhance visualisation, engagement, and academic performance. The findings contribute to digital pedagogy in TVET and support scalable adoption of AR-based instructional tools aligned with engineering curriculum standards.

This study focuses on the development and evaluation of an Augmented Reality-based e-Module specifically designed for the topic Introduction to Power Systems. The module integrates AR content using Zapworks and Zappar, and is accessible via Android and iOS mobile platforms to ensure compatibility across devices. The sample consists of second-year students from the Bachelor of Electronic Engineering programme at Universiti Tun Hussein Onn Malaysia, enrolled in the Power Systems course during the second semester of the 2024/2025 academic session. These students were selected due to the abstract and complex nature of the subject, which benefits from enhanced visualisation provided by AR. The effectiveness of the e-Module is evaluated using a quasi-experimental design, with comparisons made between post-test results of a control group and a treatment group. Student acceptance is also assessed through structured questionnaires focusing on design, content, and functionality. However, the scope of this study is limited in several ways: the module only covers a single topic within the Power Systems course, the participants are restricted to one institution and one academic cohort, and the evaluation period is confined to a single semester. These limitations may affect the generalisability of the findings, but they provide a valuable foundation for future expansion of AR applications in TVET contexts.

Augmented Reality (AR) has gained increasing attention in education due to its ability to enhance motivation, learner engagement, and understanding of abstract concepts. Several studies (Udaya Shankar et al., 2023; Soltani & Morice, 2020; Kazakou & Koutromanos, 2023; Algerafi et al., 2023) highlight the advantages of AR in supporting learning retention and interactive visualization. However, most of these works focus on science, mathematics, and general engineering education, while its application in specialized domains such as Power Systems remains limited. Within the TVET context, AR has been applied to simulate practical skills such as welding and machine repair (Chandrasekar, 2022; Dede et al., 2019), as well as to address infrastructure limitations through virtual laboratories (Sirakaya & Alsancak Sirakaya, 2022). Although these studies report

improvements in learner motivation and training safety, challenges such as development costs, scalability, and the level of interactivity have also been noted.

In Power Systems education specifically, AR facilitates clearer visualization of energy flow, grid operations, and component interactions (Roopa et al., 2020; Rashid et al., 2023). Opriş et al. (2018) demonstrated that AR-based 3D models can effectively improve students' comprehension of system structures. Nonetheless, other studies (Alzahrani et al., 2020; Susan Trinoviorar et al., 2024) emphasize persistent challenges related to student acceptance, infrastructure readiness, and limitations in pedagogical design. This indicates a need for further research that not only evaluates the effectiveness of AR, but also investigates learner acceptance in terms of design, content, and functionality.

## 2. Methodology

This study employed a quasi-experimental design involving two groups of Bachelor of Electronic Engineering students ( $N = 60$ ) enrolled in the Power Systems course at Universiti Tun Hussein Onn Malaysia. The control group ( $n = 30$ ) received instruction through conventional methods, while the treatment group ( $n = 30$ ) utilized a developed AR-based e-Module designed specifically for the topic Introduction to Power Systems. Pre-test and post-test assessments were administered to both groups to evaluate learning outcomes and knowledge acquisition. Three research instruments were implemented. First, a product evaluation checklist was completed by three experts representing subject matter, pedagogy, and ICT to validate the module's design consistency, content relevance, and usability. Second, pre- and post-test items were constructed based on Bloom's Taxonomy, featuring 12 multiple-choice questions covering core topics such as energy flow, grid functions, and protective systems. Third, a student acceptance questionnaire was administered to the treatment group using a 4-point Likert scale, measuring perceptions of the module's design, content quality, and functional usability.

A pilot study involving 17 students was conducted to test the instruments for reliability and clarity. The questionnaire recorded a Cronbach's Alpha value of 0.958, indicating excellent internal consistency ( $\alpha \geq 0.70$ ). The test items were also analyzed using Difficulty Index and Discrimination Index to ensure appropriate challenge levels and item validity. During the main phase of the study, both groups consisting 30 students each, completed the pre-test before instruction and the post-test after the learning sessions. The treatment group additionally responded to the student questionnaire. Quantitative data were analyzed using paired sample t-tests to measure improvements within each group and independent sample t-tests to compare outcomes between groups. Descriptive statistics such as mean scores, frequencies, and percentages were generated using SPSS to summarize student feedback on module acceptance. Open-ended responses were also conducted to identify usability patterns and suggestions for improvement. This methodological approach ensured that each research objective was addressed with appropriate validation, measurement, and statistical rigor, allowing for a reliable assessment of the AR-based e-Module's impact on learning and usability in the Power Systems topic.

## 3. Results and Discussion

This section presents three core findings of the study, expert evaluation of the AR e-Module, the analysis of student achievement through pre and post-test comparisons and student perceptions of the AR-based e-Module for the Introduction of Power System course.

### 3.1 Expert Evaluation of the AR e-Module

A panel of seven experts evaluated the AR e-Module based on three dimensions: design, content, and usability. The design aspect received strong endorsement, with 8 out of 10 items achieving full agreement, 100%. These included the layout of content, colour selection, incorporation of animation and video, and interactivity via navigation buttons. However, two items of question, related to the quality of 3D models and design consistency were rated at 66.67%, indicating a need for improvement in multimedia fidelity and visual standardisation.

In the content dimension, all 10 items received unanimous agreement, 100%, demonstrating that the content was relevant, well-organised, accurate, and aligned with curriculum objectives. This confirms the e-Module's instructional quality and subject matter appropriateness. For usability, 8 out of 10 items received full agreement. The remaining two items, regarding button responsiveness and clarity of navigation instructions were rated at 66.67%, suggesting that minor technical adjustments could further enhance user experience. Overall, expert feedback confirms that the e-Module is educationally sound, functionally practical, and effectively designed, with recommendations for refinement in visual and interaction elements.

### 3.2 Effects on Student Achievement

To evaluate the effectiveness of the AR-based e-Module, a quasi-experimental design was implemented involving two groups of students: the control group received traditional instruction, while the treatment group used the

developed AR-based e-Module. Both groups completed identical pre-test and post-test assessments containing 15 multiple-choice items related to the Introduction to Power Systems topic.

Table 1 below shows that the p-value = 0.031, which means  $p < 0.05$ . This indicates a significant improvement in the control group’s scores, with an average increase of 6 marks between the pre-test and post-test. These findings suggest that conventional instruction was effective in enhancing students’ understanding of the Power Systems topic. Accordingly,  $H_{01}$  is rejected, confirming that respondents’ post-test scores improved significantly without the AR e-Module intervention.

**Table 1** Pre-Test and Post-Test results for the control group

Group	t	df	Sig. (2 tailed) (p)	Mean dif	Standard error diff.
Pre- Post	-2.271	29	0.031	-6.00	2.643

Table 2 below shows the treatment group also recorded a significant improvement ( $p < 0.001$ ), with a higher average increase of about 10 marks compared to the pre-test. This suggests that the AR-based e-Module was effective in supporting student learning, leading to greater score gains than conventional methods.. As such,  $H_{02}$  is rejected.

**Table 2** Pre-Test and Post-Test results for the treatment group

Group	t	df	Sig. (2 tailed) (p)	Mean dif	Standard error diff.
Pre- Post	-4.446	29	<0.001	10.222	2.299

An independent samples t-test was conducted to examine whether there was a significant difference in pre-test scores between the control and treatment groups. As shown in Table 3, the p-value is 0.358 ( $p > 0.05$ ), indicating no statistically significant difference between the two groups. This confirms that both groups began the study with relatively similar levels of prior knowledge.

**Table 3** Pre-Test results between the control group and the treatment group

Test	Group	t	df	Sig. (2 tailed) (p)	Mean dif	Standard error diff.
Pre	Control	0.927	58.0	0.358	3.334	3.597
	Treatment		56.5			

Table 4 shows that the p-value for the post-test comparison between the control and treatment groups is 0.796 ( $p > 0.05$ ). This indicates that there was no statistically significant difference in post-test scores between the two groups. In other words, the integration of the AR-based e-Module did not result in a measurable improvement in student achievement compared to conventional instruction.

**Table 4** Post-Test results between the control group and the treatment group

Test	Group	t	df	Sig. (2 tailed) (p)	Mean dif	Standard error diff.
Post	Control	-0.260	58.0	0.796	-0.889	3.417
	Treatment		57.2			

### 3.3 Students' Acceptance

**Table 5** Mean Score for Design, Content and Functionality aspects

Aspect	Mean Score	Interpretation (4-Point Likert Scale)
Design	3.776	Very High
Content	3.754	Very High
Functionality	3.819	Very High

Overall, the design aspect recorded a mean score of 3.776, which falls under the Very High category based on the four-point Likert scale. This reflects that the content layout, colour schemes, button design, and interactivity met students' expectations and effectively supported their engagement and understanding. For the content aspect, the mean score was 3.754, also in the Very High category. The module's content, covering concept explanation, example relevance, topic arrangement, and supplementary materials such as videos and quizzes was found to be highly relevant and supportive of learning objectives.

Meanwhile, the functionality aspect achieved the highest score of 3.819, indicating that the use of AR technology via the Zappar app provided an accessible, clear, and user-friendly learning experience. Easy access to notes and interactive displays, along with intuitive navigation design, contributed to a deeper understanding of the Power Systems course. In summary, all three aspects of student acceptance recorded very high mean scores (>3.7), confirming that the AR e-Module is well received in terms of design, content, and functionality. Interestingly, however, statistical analysis showed no significant difference in academic performance between the treatment and control groups. This suggests that while students highly valued and enjoyed the module, longer exposure and deeper integration into teaching may be needed before it translates into measurable improvements in learning outcomes.

### 3.4 Discussion

This chapter discusses the findings in relation to the research questions, theoretical framework, and literature reviewed. The discussion is organized according to the main research objectives: (i) the development of the AR-based e-Module, (ii) its effect on student achievement, and (iii) student acceptance in terms of design, content, and functionality. The analysis also reflects on why high levels of acceptance did not translate into significant performance gains, linking the findings to the Successive Approximation Model (SAM) and behaviorist principles.

### 3.5 Discussion on the Development of the Power Systems e-Module

The findings confirm the importance of Technology-Based Teaching Aids (TBTAs) in supporting the learning of abstract engineering concepts. As shown in this study, AR visualizations enabled students to analyze systemic relationships in Power Systems more effectively, aligning with Alhamrouni et al. (2024) who argue that visual tools enhance interactivity and critical thinking. Furthermore, the development process, guided by the Successive Approximation Model (SAM), proved effective as it allowed iterative prototyping, continuous feedback, and refinement in alignment with learner needs (Hasil et al., 2025; Wolverson, 2022).

From a pedagogical standpoint, the module incorporated behaviorist principles through repetitive quizzes and immediate feedback, providing reinforcement that gradually strengthened conceptual understanding (Ali, 2021; Iskandar et al., 2022). This aligns with Wolverson (2022), who highlights that repetition and reinforcement embedded in interactive technologies foster retention of technical concepts. Thus, SAM provided the structural design approach, while behaviorism informed the pedagogical delivery, together contributing to a learner-centered and flexible AR-based e-Module. Expert validation further confirmed the content's relevance, though limitations were identified in design and functionality, particularly with 3D elements. These constraints were mainly due to the Zapworks platform, which struggled with rendering stability and smooth 3D integration. Despite improvements made to text layout and navigation flow, technical instability persisted. This illustrates the challenge of balancing pedagogical design with technical feasibility—a recurring issue in AR-based learning tools.

### 3.6 Discussion on the Effect of the AR e-Module on Students' Achievement

The quasi-experimental results showed that both control and treatment groups improved from pre-test to post-test. In the control group, the improvement was modest but statistically significant. This likely reflects general learning effects such as test familiarity and natural progression (Llido et al., 2025; Gliner et al., 2021), rather

than being attributable to instructional innovation. For the treatment group, a larger improvement was observed within-group, consistent with prior research showing AR's capacity to enhance engagement and conceptual clarity (Ewis, 2024; Koumpouros, 2024). However, when compared directly with the control group, the post-test differences were not statistically significant. This finding is important: while students perceived the AR module positively, its short-term impact on performance was limited.

Several factors may explain this. First, technical limitations of Zapworks reduced the immersive quality of the AR experience, limiting the pedagogical potential (Alhamrouni et al., 2024). Second, limited exposure time may have constrained deeper learning (Ibáñez & Delgado-Kloos, 2018). Third, the simultaneous use of text, animation, and audio may have induced cognitive overload, as explained by Mayer's (2024) cognitive theory of multimedia learning. Finally, the novelty effect of AR may have temporarily increased attention without sustaining learning outcomes (Radu, 2020). From a theoretical perspective, this gap between high engagement and modest performance can be understood through behaviorism, reinforcement mechanisms were present e.g. in quizzes, but the limited duration and frequency of reinforcement reduced their effectiveness. Similarly, SAM's iterative design allowed for user-friendly development, but the short intervention period prevented students from fully internalizing the material. This suggests that to produce measurable achievement gains, AR interventions must be embedded more extensively across topics, with prolonged exposure and stronger scaffolding.

### 3.7 Discussion on Students' Acceptance of the AR e-Module in Terms of Design, Content, and Functionality

Student acceptance of the Power Systems AR e-Module was evaluated through three main aspects: content, functionality, and design. The average mean scores for each aspect were high, with 3.754 for content, 3.819 for functionality, and 3.776 for design. These results demonstrate that the SAM-driven iterative process succeeded in producing a module that met learners' expectations in terms of usability and relevance. Students valued structured content delivery, engaging layouts, and the interactivity enabled by AR, reflecting the motivational benefits reported in prior studies (Ibáñez & Delgado-Kloos, 2018; Sadjı Evenddy et al., 2024).

From a behaviorist lens, the high acceptance scores highlight the effectiveness of reinforcement and immediate feedback in sustaining student motivation. The use of interactive quizzes, multimedia, and symbolic rewards likely contributed to positive perceptions. However, the disjunction between very high acceptance (mean >3.7) and non-significant performance gains indicates that usability and engagement, while necessary, are not sufficient conditions for learning improvement. Students themselves pointed out areas for enhancement, including rotatable 3D models, clearer audio, and multimodal supports such as additional references and voiceovers. These align with cognitive load theory, suggesting that reducing extraneous demands and diversifying representations may strengthen learning outcomes. In summary, the findings suggest that the AR e-Module has strong potential as a pedagogical tool for Power Systems education in TVET, particularly in terms of usability and motivation. However, its impact on achievement requires extended use, stronger instructional integration, and more robust technical infrastructure.

The findings of this study suggest several areas where the Power Systems AR e-Module can be further refined to enhance its effectiveness in technical education. First, learning videos should be designed to be shorter, more dynamic, and supported with clearer audio narration to sustain focus and reduce extraneous cognitive load, consistent with Mayer's (2024) Cognitive Theory of Multimedia Learning. Additionally, the integration of responsive interactive icons and manipulable 3D models is strongly recommended, as direct object manipulation has been shown to significantly improve learners' conceptual understanding and cognitive engagement in AR environments (Lee & Wong, 2023; Ibáñez & Delgado-Kloos, 2018). These enhancements would allow students to more effectively visualize and explore abstract technical concepts, thereby aligning the module more closely with the demands of engineering education.

Equally important are ergonomic and accessibility improvements that ensure the module is usable across diverse contexts. The interface layout should incorporate appropriate icon sizing, balanced spacing, and streamlined navigation, particularly for mobile device users. The delivery of multimodal content including audio explanations, graphical aids, and supplementary references would further support diverse learning preferences and foster deeper comprehension (Alhamrouni et al., 2024; Koumpouros, 2024). Moreover, the physical requirement to continuously hold a device while engaging with AR features poses challenges for prolonged use; thus, ergonomic considerations must be integrated into future iterations to support learner comfort and sustained engagement (Vrcelj et al., 2023). Taken together, these targeted improvements could substantially enrich the learning experience, increase usability, and maximize the pedagogical value of AR-based modules in vocational and technical education settings.

## 4. Conclusion

This study developed and evaluated an Augmented Reality (AR)-based e-Module for the Power Systems course, designed using the Successive Approximation Model (SAM) and grounded in behaviorist learning principles. Expert validation confirmed its quality in terms of design, content, and functionality, while student feedback reflected very high acceptance (mean > 3.7) across all aspects. Although no significant difference in achievement was observed between the treatment and control groups, the module successfully enhanced engagement, usability, and motivation in learning abstract concepts. The findings highlight the potential of AR as a complementary teaching tool in Technical and Vocational Education and Training (TVET), particularly for abstract and complex engineering subjects. With further refinement in 3D interactivity, extended exposure time, and broader integration across courses, AR-based modules can play an important role in supporting TVET's digital transformation and alignment with the demands of the Fourth Industrial Revolution (IR 4.0).

## Acknowledgement

The authors would like to express their gratitude to the Faculty of Technical and Vocational Education at Universiti Tun Hussein Onn Malaysia for their support.

## Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

## Author Contribution

The authors confirm contribution to the paper as follows: **study conception and design:** Mustika Rawiah Azidin; **data collection:** Mustika Rawiah Azidin; **analysis and interpretation of results:** Mustika Rawiah Azidin; **draft manuscript preparation:** Mustika Rawiah Azidin. All authors reviewed the results and approved the final version of the manuscript.

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