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Split Unit PCB Diagnosis Kit (Kit-DPUP) As A Teaching Aid

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Abstract: In the evolving landscape of Technical and Vocational Education and Training (TVET), the Split Unit PCB Diagnosis Kit (KIT-DPUP) emerges as an innovative teaching aid designed to enhance the learning experience in HVAC systems. This study explores the integration of KIT-DPUP within TVET, highlighting its role in bridging the gap between theoretical knowledge and practical application. Through a structured approach utilizing the ADDIE development model, the research outlines the creation, implementation, and evaluation of the KIT-DPUP, emphasizing its potential to provide hands-on experience and improve the comprehension of complex HVAC concepts. The methodology includes a thorough analysis, design, development, and evaluation phase, culminating in a robust assessment by five panels of experts. The findings reveal a high level of agreement on the kit's design, development, and functionality, evidenced by the Item Content Validity Index (I-CVI) values ranging from 0.8 to 1.0 and the Scale-Content Validity Index (S-CVI) averaging 0.98 for functionality and 1.00 for both design and development aspects. These results underscore the kit's alignment with established product development characteristics and pedagogical effectiveness. The study underscores the importance of innovative teaching aids in maintaining student interest, diversifying instructional methods, and preparing a skilled workforce for the challenges of the modern industry. Recommendations for further enhancements are discussed to optimize the educational impact of the KIT-DPUP. The study concludes that the KIT-DPUP stands as a testament to the efficacy of practical, interactive learning tools in technical education, aligning with the broader goals of TVET to provide quality, industry-relevant education.

Keywords: Technical Vocational Education and Training (TVET); HVAC Education; Split Unit PCB Diagnosis Kit (KIT-DPUP); Innovative Teaching Aids; Content Validity Index (CVI)

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1. Introduction

Education forms the foundation of a knowledgeable and skilled generation (Idris *et al.*, 2012). As Deputy Prime Minister Datuk Seri Zahid Hamidi emphasised, Technical and Vocational Education and Training (TVET) institutions are crucial for national development, particularly in the Industry Revolution 4.0 and the digital era (Malay Mail, 2023). In this landscape, diverse students' psychological backgrounds and intellectual abilities necessitate structured lesson plans and practical teaching aids (Jonid & Hashim, 2010). Teaching aids, especially in theory-heavy subjects, are pivotal in engaging students and facilitating learning (Biden & Kamin, 2013). This is where tools like the Split Unit PCB Diagnosis Kit (KIT-DPUP) come into play, bridging the gap between theoretical knowledge and practical application. This simulation kit is designed to replicate real-life faults in indoor air-conditioning units to enhance the learning experience for students in HVAC (Heating, Ventilation, and Air Conditioning) systems.

The responsibility of education is a collective one (Idris, 2012), with educators playing a significant role in delivering quality material (Wiryomartono, 2018; Joseph, 2015). As Buntat and Ahamad (2012) suggest, educators need to devise strategies for effective teaching, and teaching aids are instrumental in this process (Uchechi, 2021). For technical students, practical and simulated learning experiences are essential for comprehensively understanding their subjects (Hamdan & Mohd Yasin, 2010; Mok, 2000). This is particularly relevant in fields like HVAC, where hands-on experience with systems is crucial.

As studied by Rimal (2023), the effectiveness of vocational training highlights the importance of physical facilities and modern technology in training environments. This underscores the need for contemporary and relevant teaching aids like the KIT-DPUP in TVET institutions. Furthermore, Sebola (2022) discusses the role of TVET colleges in higher education, emphasizing the need for high standards in educational tools and methods to maintain the quality of education.

The challenge of maintaining student interest and avoiding monotony in teaching methods is well-documented (Bruner, 2001; Kasim & Yusoff, 2006). Innovative teaching aids, whether electronic or non-electronic, are crucial in enhancing student understanding and maintaining interest (Hanif *et al.*, 2016). The KIT-DPUP, as a simulation teaching kit, is designed to provide real-life troubleshooting experiences in air-conditioning systems, making it an invaluable tool in technical education.

In conclusion, the development of the KIT-DPUP as a teaching aid aligns with the broader goals of TVET in providing quality education that is both engaging and relevant to industry needs. Its design, development, and testing are steps towards enhancing the educational experience in technical fields, ensuring that students are well-prepared for the challenges of the modern workforce.

2. Literature Review

Technical and Vocational Education and Training (TVET) is pivotal in equipping students with the practical skills necessary for the modern workforce, particularly in the context of the fourth industrial revolution and disruptive technologies. Tuenpusa *et al.* (2021) emphasize the impact of disruptive technology on the workforce and the essential role of TVET in developing skills pertinent to this new era. Their research underscores the necessity of increasing labour skills and educating new workers to adapt to advanced technologies, highlighting the need for a professional standardization process in TVET to meet the required work standards in the era of Disruptive Technology. Similarly, Yisihak and Cai (2020) discuss the importance of establishing well-equipped artificial intelligent manufacturing training centres within the TVET sector. They argue that such centres are crucial for economic development and industrialization, as they help produce a well-educated and skilled workforce for modern intelligent industries.

However, the effectiveness of TVET graduates in the workforce is a subject of concern. Olabiyi and Chinedu (2018) explore employers' perceptions of the competency of TVET graduates in Nigeria, revealing dissatisfaction with their skill levels. This indicates a gap between the training provided and the industry requirements, suggesting a need for better integration of emerging technology tools and resources in TVET programs. The study recommends using adequate planning and management of these tools to contribute enormously to the quality and sustainability of the workforce.

In the realm of technical education, particularly in HVAC systems, the role of innovative teaching aids is becoming increasingly crucial. The Split Unit PCB Diagnosis Kit (KIT-DPUP) is designed to bridge the gap between theoretical knowledge and practical application. By providing hands-on experience in refrigeration and air conditioning diagnostics, the KIT-DPUP responds directly to the needs highlighted by Geda (2021), who emphasized the importance of aligning education with recognized occupational standards and the necessity of practical components and industry training in TVET.

The development and implementation of the KIT-DPUP follow a structured approach, utilizing the ADDIE development model to ensure a comprehensive and effective educational tool. This aligns with the broader goals of TVET in providing quality education that is engaging and relevant to industry needs. The kit's design, development, and testing are steps towards enhancing the educational experience in technical fields, ensuring that students are well-prepared for the challenges of the modern workforce.

In conclusion, the literature indicates a clear need for TVET to adapt to the changing demands of the workforce, particularly in the face of disruptive technologies. Innovative teaching aids like the KIT-DPUP play a crucial role in this adaptation, providing practical, hands-on experience that aligns with industry standards and enhances student learning. As TVET continues to evolve, it must incorporate such tools and strategies to maintain its relevance and effectiveness in preparing students for the future.

3. Methodology

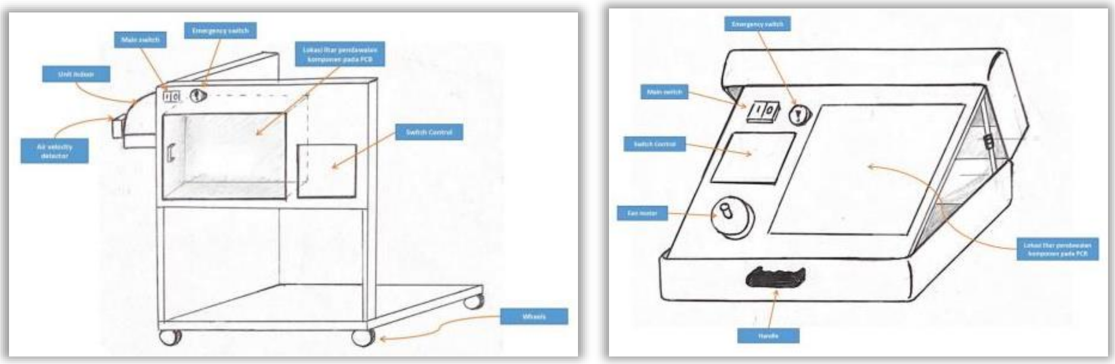
This study follows a structured approach, utilizing the ADDIE development model to guide the creation of the Split Unit PCB Diagnosis Kit (Kit-DPUP) as a teaching aid. The ADDIE model, comprising the Analysis, Design, Development, Implementation, and Evaluation phases, is a widely recognized framework in educational technology and instructional design (Branch, 2009). This model is particularly suitable for developing educational tools due to its systematic, iterative nature, which ensures a comprehensive development process (Gustafson & Branch, 2002).

3.1 Analyze Phase

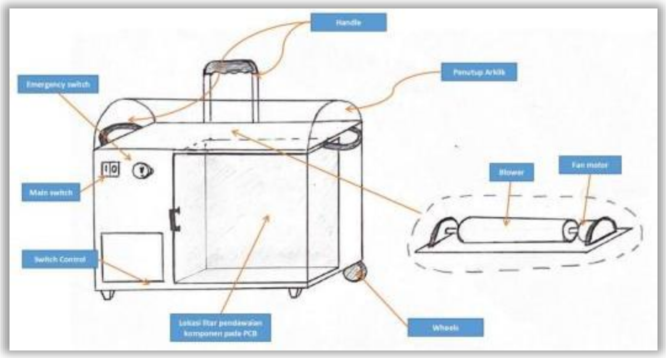
The initial phase involved a thorough review and observation to identify gaps and needs in current learning sessions. This involved defining the study's scope, formulating the problem statement, and assessing existing designs and materials pertinent to the Kit-DPUP's development. Key sources, including relevant literature and empirical studies on PCB diagnosis and educational tools, informed this phase (Smith & Ragan, 2005).

3.2 Design Phase

During the design phase, three conceptual designs were generated and subjected to an evaluation process. The final design selection incorporated an evaluation matrix, focusing on factors such as user needs, safety, cost, size, and ergonomics, aligning with user-centred design principles (Norman, 2013). The chosen design was rendered using Sketch-Up, facilitating a detailed visual representation of the proposed teaching kit. Figure 1 shows the three design concepts to be evaluated using a questionnaire before final design selection.



(a) (b)



(c)

Figure 1. Three designs concepts

After deciding the most suitable design for the teaching kit, the researcher produced the final selection product design drawing using Sketch-Up. Figure 2 shows the final design of the product.

Figure 2. Final drawing of the product design

3.3 Development Phase

The development phase entailed creating the Kit-DPUP, encompassing the model framework and construction of the diagnosis system. This phase accounted for resource allocation, including financial, media, and human resources, paralleling project management best practices (Project Management Institute, 2017). The outcome was a functional prototype, as depicted in the corresponding figures. Figure 3 shows the final result of the Kit-DPUP product assembled and developed, from measurement, cutting, and wiring to connection and installation to tidying up.

Figure 3. The final product has been developed

In addition, to make it easier for users to handle this product, the researcher has also prepared a user manual in the form of a booklet. Figure 4 shows the user manual prepared by the researcher.

Figure 4. Kit-DPUP's user manual

3.4. Implementation Phase

Upon completion of the Kit-DPUP, the implementation phase involved testing its functionality. This stage is critical in instructional design, ensuring that the educational tool meets its intended objectives and operates as expected (Dick *et al.*, 2009).

3.5. Evaluation Phase

The Evaluation Phase plays a critical role in developing the Kit-DPUP, involving an in-depth assessment by a panel of experts. According to educational research guidelines, the number of experts in such evaluations should be sufficient to provide comprehensive feedback while remaining manageable. For this study, a panel of 5 experts is selected, which aligns with the recommended range of 5 to 15 experts for effective content validation (Wyatt, 2005). This panel composition ensures a diverse and thorough evaluation, encompassing various aspects of the Kit-DPUP, where they assess the technical accuracy and relevance of the kit and evaluate the kit's pedagogical effectiveness and user-friendliness.

The evaluation utilizes two primary instruments: 1) An Expert Verification Form, which gathers detailed feedback on design, content accuracy, usability, and overall effectiveness as a teaching aid and 2) A Questionnaire designed to assess how well the kit fulfils its intended learning objectives and to gather quantitative data on its effectiveness. This comprehensive evaluation approach ensures the Kit-DPUP is not only technically sound but also pedagogically robust, adhering to best practices in educational research and development (Hsu, 2003).

3.6. Research Instrument

In this study, the primary research instrument, a structured questionnaire, is employed to assess the Split Unit PCB Diagnosis Kit (Kit-DPUP) in terms of its design, development, and functionality as a teaching aid. This questionnaire was developed following established best practices in survey design (Gehlbach & Artino Jr., 2018) and included various question types like dichotomous, ranking, and rating scales. To enhance the questionnaire's validity, it was rigorously reviewed and validated by three experts in the HVAC field, ensuring its relevance and accuracy in evaluating educational technology in engineering. Special attention was paid to the phrasing of questions, labelling of response options (Artino Jr. & Gehlbach, 2012), and the sequencing of questions (Gehlbach & Brinkworth, 2011) to minimize bias and enhance clarity. The validated questionnaire was then distributed to a selected group of HVAC professionals, ensuring informed and representative feedback.

4. Results

This section delineates the data analysis and the findings derived from questionnaires distributed to experts in Heating, Ventilation, and Air Conditioning (HVAC) and electrical engineering. The questionnaire encompassed three primary constructs: design, development, and functionality of the Kit-DPUP. To measure and analyze the experts' level of agreement with the product, the Item Content Validity Index (I-CVI) method was employed.

According to Shi *et al.* (2012), a scale exhibits excellent content validity when it achieves an I-CVI of 0.78 or higher, coupled with Scale-Content Validity Index/Universal Agreement (S-CVI/UA) and Scale-Content Validity Index/Average (S-CVI/Ave) of 0.8 and 0.9 or higher, respectively. The analysis of the content validity index for the obtained items is presented in Tables 1, 2, and 3. These tables elucidate the extent to which the items align with the established criteria for content validity, reflecting the consensus among the consulted experts regarding the kit's design, development, and functionality.

Table 1. Expert Evaluation of Kit-DPUP on Design Aspects

No	Item	Yes	No	I-CVI	UA
1.	The design of this product is safe to use	5	-	1	1
2.	The design is easy to handle	5	-	1	1
3.	The design of this product is strong	5	-	1	1
4.	The size of this product is suitable for use in the classroom	5	-	1	1
5.	The installation of components on the testing board is neat	5	-	1	1
6.	The order of components on the testing board is according to the original order on the PCB of the split unit	5	-	1	1
7.	The entire product is in neat condition	5	-	1	1
8.	The product is easy to maintain	5	-	1	1
		S-CVI/Ave		1.00	
		S-CVI/UA			1.00

Upon evaluation, the Item Content Validity Index (I-CVI) values for the design aspect of the kit ranged from 0.8 to 1.0, with all items achieving a perfect score of 1.0, as shown in Table 1. This unanimous rating reflects the experts' consensus on the product's neat and practical design. Consequently, the average Scale-Content Validity Index (S-CVI) for the design aspect also reached the optimal value of 1.00. Given that the recommended threshold for S-CVI in content validity studies is 0.8, the obtained S-CVIs for this aspect significantly exceed the standard, indicating a high level of agreement among the evaluators regarding the kit's design quality.

Table 2. Expert Evaluation of Kit-DPUP on Development Aspect.

No	Item	Yes	No	I-CVI	UA
1.	The selection of materials for this product is suitable	5	-	1	1
2.	The connection of the components on this product is neat	5	-	1	1
3.	The position of the components on this product is in order	5	-	1	1
4.	The installation of this product is strong	5	-	1	1
5.	This product uses real components from the industry	5	-	1	1
6.	The product meets the safety features for user use	5	-	1	1
7.	The product meets the comfort characteristics for user use	5	-	1	1
		S-CVI/Ave		1.00	
		S-CVI/UA			1.00

Experts assessing the development aspect of the kit reported Item Content Validity Index (I-CVI) values ranging from 0.8 to 1.0. Notably, all items achieved the maximum score of 1.0, indicating that the product fully aligns with established product development characteristics, as shown in Table 2. Similarly, the Scale-Content Validity Index (S-CVI) for the development aspect reached an optimal average of 1.00. This is well above the recommended S-CVI threshold of 0.8 for content validity, demonstrating that the S-CVI scores for this aspect significantly surpass the standard and reflect a strong consensus among evaluators regarding the kit's development quality.

Table 3. Expert Evaluation of Kit-DPUP on Functionality.

No	Item	Yes	No	I-CVI	UA
1.	The LED light on the display board lights up well	5	-	1	1
2.	System protection components, which are RCCB and MCB, can work well	5	-	1	1
3.	An emergency switch can cut off the supply current immediately	5	-	1	1
4.	The ON/OFF switch for fault simulation works during the diagnosis process.	5	-	1	1
5.	The testing point on the testing board works during the component diagnosis process	5	-	1	1
6.	The product can operate safely	5	-	1	1
7.	The product is suitable for diagnosing the PCB of the split unit	5	-	1	1
8.	This product can diversify the way the instructor teaches in the classroom	5	-	1	1
9.	This product can help make it easier for users to perform diagnosis	5	-	1	1
10.	The provided QR code can give notes to students about PCB circuit components	5	-	1	1
11.	Standard operating procedure (SOP) is easy to understand	4	1	0.8	0
12.	The provision of a user manual can help lecturers operate the product easily	5	-	1	1
13.	Overall, this product works well	5	-	1	1
		S-CVI/Ave		0.98	
		S-CVI/UA			0.92

Experts evaluating the functionality aspect of the kit reported Item Content Validity Index (I-CVI) values ranging from 0.8 to 1.0. Notably, one item did not achieve the maximum score of 1.0 due to the poorly understood Standard Operating Procedure (SOP). Consequently, the average Scale-Content Validity Index (S-CVI) for the functionality aspect is 0.98, which, while slightly below perfection, still significantly exceeds the recommended S-CVI threshold of 0.8 for content validity, as shown in Table 3. This indicates that, despite the noted issue with the SOP, the S-CVI scores for this aspect generally reflect a robust level of agreement among the evaluators regarding the kit's functionality.

5. Discussions and Conclusions

The evaluation and feedback from five experts have yielded a predominantly positive response towards the developed Split Unit PCB Diagnosis Kit (KIT-DPUP). However, they have also recommended several enhancements to augment the product's effectiveness as a teaching aid. Specifically, experts suggest refining the design and labelling of product components to ensure they are orderly, complete, and neat. Developing a comprehensive and user-friendly manual and a QR code containing essential and succinct information has also been advised (Durak *et al.*, 2016). These enhancements are crucial for optimizing Kit-DPUP's utility and effectiveness in educational settings.

QR codes significantly enhance the accessibility of educational content, providing students with immediate access to a wide range of resources (Chen, 2017). By scanning a code, learners can unlock detailed instructions, interactive tutorials, and supplementary materials relevant to their study topic (This instant access keeps students engaged and supports a seamless learning experience by minimizing disruptions. Adopting QR codes in educational settings aligns with the just-in-time learning model, offering resources precisely when learners need them (Tan & Lim, 2020). In the context of HVAC education, students can scan QR codes to receive real-time guidance as they navigate through complex diagnostic processes, enhancing their understanding and proficiency.

QR codes can link to various types of educational content, catering to different learning preferences (Smith *et al*., 2018). Whether students are visual, auditory, or kinesthetic learners, QR codes can direct them to the most suitable resources, ensuring a more inclusive and personalized learning experience. Using QR codes in the Kit-DPUP encourages learners to participate actively in their education (Williams & Brown, 2020). By exploring content at their own pace and revisiting concepts as needed, students develop critical thinking and problem-solving skills essential for technical fields.

While QR codes offer numerous educational benefits, it is crucial to ensure the quality and relevance of the linked content (Anderson & Thompson, 2021). Future research should focus on optimizing the resources accessible via QR codes and investigating how these resources impact learning outcomes.

In summary, the Split Unit PCB Diagnosis Kit (Kit-DPUP) has been successfully developed to meet its intended objectives, serving as a valuable Teaching Aid Material (TAM) for educators and students in the HVAC field, particularly for courses on Refrigeration and Air Conditioning Diagnosis and Analysis System. The kit's development aligns with the growing recognition of the importance of concrete teaching materials in enhancing the comprehension of abstract topics (Anderson & Thompson, 2018). With its potential for long-term use, the Kit-DPUP is a testament to the efficacy of innovative educational tools in technical education (Williams, 2020).

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