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PAPER

Development of Internet of Things Trainer Kit as a Learning Media for Digital Circuit Subjects in Higher Education

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ABSTRACT

This research and development project aimed to create learning materials in the form of an Internet of Things (IoT) trainer kit specifically designed for the Digital Circuit course. The goal was to enhance student motivation and learning outcomes by facilitating a comprehensive understanding of the subject matter. The research methodology employed was research and development (R&D) utilizing the Instructional Development Institute (IDI) development model, which consists of define, develop, and evaluate stages. Primary data were gathered from experts in instrumentation, media, and materials, as well as feedback from lecturers and students. The findings revealed a high level of validity for the IoT trainer kit learning media. Media experts assigned a validity value of 0.93, while material experts provided a validity value of 0.86. The practicality of the media was confirmed by favorable responses from lecturers, indicating a practicality score of 87.31%. Additionally, students' responses after the trial reflected a high practicality rating of 83.25%. Regarding effectiveness, the IoT trainer kit learning media demonstrated success in improving student learning outcomes, with a gain score of 77.25%, affirming its effectiveness. In conclusion, the IoT trainer kit Learning Media is considered valid, practical, and effective for teaching digital circuits within the Electrical Engineering Study Program at Muhammadiyah University of West Sumatra. Its utilization is expected to boost student engagement, creativity, and learning outcomes, potentially improving the overall quality of education.

KEYWORDS

learning media, trainer kit, Internet of Things (IoT), digital circuit subjects, higher education

1 INTRODUCTION

Education serves as the cornerstone of a nation, aiming to nurture proficient human resources. Enhancing the potential of students, who represent the upcoming

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generation of the nation, is crucial through education to cultivate critical, rational, and imaginative thinking skills [1]. Education plays a pivotal role in shaping individuals, fostering self-development, and empowering their potential to interact with nature and the environment in meaningful ways [2]. Consequently, there is a continual need for improvement to enhance the quality of education for future generations [3].

The significance of education in shaping skilled, intelligent, and competitive human resources reflects the trajectory of a nation [4]. The Muhammadiyah University of West Sumatra, as an exemplary institution of higher education, aims to become a leading establishment by promoting faith and advancing science and technology. The Faculty of Engineering, especially the Electrical Engineering Study Program, aims to conduct research in the field of electricity that businesses and industries use while also honoring local wisdom. The digital circuit courses offered by the Electrical Engineering Study Program include the study of digital systems, logic gates, and applications of the Internet of Things (IoT). Despite having sufficient facilities and infrastructure, not all courses within this program receive optimal support.

Learning media is a crucial element for educational success. Educators must utilize the available facilities and infrastructure [5], [6], and [7]. The use of learning media enhances the realism and enjoyment of learning, especially in the age of technological advancements [8]. While learning media is currently utilized for self-learning, challenges persist in creating effective, engaging, interactive, and enjoyable media [9].

Students in the Electrical Engineering Study Program, especially in the Digital Circuit course, face challenges in their learning journey. The absence of integrated learning media and difficulties in comprehending the concepts and practical applications of digital circuits pose issues [10], [11]. Thus, the proposal for the IoT trainer kit as a learning medium aims to enhance student understanding and create an engaging learning environment [12].

The trainer kit is anticipated to help students grasp the fundamental concepts of digital circuits and IoT, fostering increased interest and motivation for learning [13], [14]. By providing real-life situations, the trainer kit allows students to engage in simulations of authentic conditions [15]. The development of learning media, such as the Trainer Kit, aims to reduce passive and static learning activities, introduce variety into learning, and make the learning process more dynamic [16], [17]. Through the creation of this IoT Trainer Kit, the aim is to enhance the effectiveness, interactivity, and enjoyment of the Digital Circuit course [18]. The trainer kit can serve as a solution to address obstacles in the learning process, offering a more tangible learning experience and motivating students to actively participate in their learning [19], [20]. Previous research indicates that trainer kits are valid [9], practical [21], and enhance student learning outcomes [22] as learning tools in higher education.

The primary objective of this study is to develop a learning tool called the IoT trainer kit for the digital circuit course, designed for students in the Electrical Engineering program at the Faculty of Engineering, Muhammadiyah University of West Sumatera. Furthermore, the research aims to assess the validity, practicality, and effectiveness of the learning tool. The outcomes of this research contribute to both theoretical and practical dimensions, specifically targeting the enhancement of academic endeavors within the Electrical Engineering program at the Faculty of Engineering, Muhammadiyah University of West Sumatra. The resultant product consists of an IoT trainer kit with specific specifications and additional modules designed for optimal performance.

2 METHODOLOGY

This study utilizes the research and development (R&D) methodology, adapting the instructional development institute (IDI) model to develop the IoT trainer kit for the digital circuit course. The testing involved learning materials for the IoT trainer within the digital circuit course, conducted at the Electrical Engineering Study Program, Faculty of Engineering, University of Muhammadiyah Sumatra Barat. The IDI model used in this study is the one-group pre-posttest design, a pre-experimental design that includes both pre-test (evaluation before treatment) and post-test (evaluation after treatment) stages conducted within a single group. Specifically, the study was conducted on [23], the 3rd semester student class of the Bachelor of Electrical Engineering at the Faculty of Engineering, Muhammadiyah University of West Sumatera, during the odd semester of the 2023–2024 academic year.

The IDI model follows a systematic approach comprising three primary stages: define, develop, and evaluate. During the define stage, background analysis and problem identification are conducted through observations to identify gaps between lecturers and students. It involves analyzing learning objectives, determining media requirements, and incorporating curriculum analysis and student characteristics. The development stage encompasses media selection, prototype design, and validation. The IoT trainer kit media is developed based on learning outcomes and validated by media and material experts. The evaluation stage focuses on product validation testing, limited trials, practicality assessments, and effectiveness evaluations. The complete flow of this development research can be seen in Figure 1.

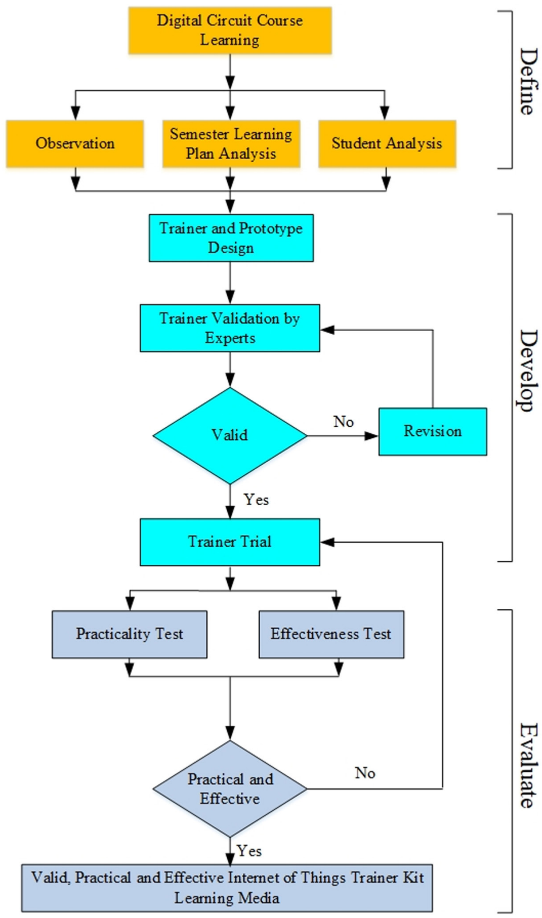

Fig. 1. Learning media development design of Internet of Things trainer kit

The validity of learning media is determined using Aiken's V statistical formula [24], with validity categories outlined in Table 1.

Table 1. Learning media validity categories

Category	Score Range
Valid	≥ 0,67
Invalid	< 0,67

Assessment is conducted by evaluating practicality through a questionnaire that gathers responses from both lecturers and students [25]. Additionally, effectiveness is measured by assessing student learning outcomes using pre- and post-test scores as indicators of learning effectiveness through the gain score (g) value [26]. The classifications for media practicality and media effectiveness are presented in Tables 2 and 3, respectively.

Table 2. Learning media practicality categories

Category	Achievement Level (%)
Very Practical	81–100
Practical	61–80
Quite Practical	41–60
Less Practical	21–40
Not Practical	0–20

Table 3. Learning media effectiveness categories

Category	Achievement Level (%)
Effective	g > 76
Moderately Effective	56 > g < 75
Less Effective	40 > g < 55
Not Effective	g < 40

This research outlines systematic steps to ensure that the IoT trainer kit serves as a valid, practical, and effective learning tool to enhance student outcomes, activities, and motivation in the digital circuit course.

3 RESULTS AND DISCUSSION

After collecting research data, the results of the data collection are described. This IoT trainer kit was developed to enhance students' skills, creativity, and independence in digital circuit lectures. The development of this trainer is carried out using the IDI development model. In this study, the evaluation stage involves a practicality test and an effectiveness test.

This IoT trainer kit has undergone validation, practicality, and effectiveness testing by experts, practitioners, and students. Before conducting the trial, the validation and practicality instruments used for data collection were first validated. Afterward, the instruments that have been deemed valid are utilized to assess the validity and practicality of the IoT trainer kit that was developed. The elucidation of research data regarding the development of a microcontroller-based IoT trainer kit for educational purposes is outlined below.

3.1 Results of the discovery stage (define)

The discovery phase (definition) is implemented to gain an understanding of the current conditions in the field. This stage involves an analysis of the requirements (needs analysis) essential for creating learning materials for the IoT trainer kit.

Curriculum analysis involves examining the synopsis of the Digital Circuit course and the semester learning plan to ensure alignment with the intended learning outcomes. The course, worth 3 credits (2 theory credits and 1 practical credit), is mandatory for students. It covers fundamental aspects of digital systems, such as numerical systems, logic gates, comprehension of sequential and combinational circuits, the IoT concept, the ESP8266 NODEMCU microcontroller, Arduino IDE programming, the installation and configuration of Arduino IDE, and the installation and configuration of trainer kit applications on the IoT software platform. Additionally, students learn about how the ESP8266 microcontroller interacts with sensors and actuators.

According to the semester learning plan, computer simulation-based media is currently being used for this course. This information serves as the foundation for developing a microcontroller-based IoT trainer kit designed to help students and lecturers simulate real-world conditions during classroom learning.

Student analysis is conducted to understand the characteristics of the research subjects, who are third-semester students in the Electrical Engineering Undergraduate Study Program at the Faculty of Engineering, Muhammadiyah University of West Sumatera, during the odd semester of the academic year from October 2023 to January 2024. These students, aged 18–24 generally possess the ability to analyze and formulate hypotheses when faced with problems. Consequently, there is a need for learning approaches that facilitate the enhancement of students' critical thinking skills and analytical abilities, especially in the field of digital circuits, with a focus on the microcontroller-based Internet of Things.

The outcomes of the curriculum and student analyses serve as the foundation for planning and designing a microcontroller-based IoT trainer kit. Through the development of this kit, the aim is to facilitate students and lecturers in conducting more realistic and meaningful learning experiences by incorporating authentic IoT simulations relevant to the field.

3.2 Results of the development phase (Develop)

The development stage in creating the IoT trainer kit media is a critical phase that involves a series of detailed steps to produce a product that is not only functional but also meets learning needs. After obtaining the results of the discovery stage, the first step is to design a prototype by referring to the findings of the initial study in the digital circuit course. The resulting prototype is a microcontroller-based media trainer kit, which is expected to effectively meet the needs of digital circuit learning. This process involves the initial design of the product using data and information obtained from the analysis of learning needs, course characteristics, and student profiles.

The design is represented through drawings or schematics, which consist of input blocks, process blocks, output blocks, and power supply blocks. These blocks are made up of detailed components such as light sensors, NodeMCU ESP8266 micro-controllers, OLED displays, relays, active buzzers, servo motors, and various other sensors. The preliminary design of the IoT trainer kit media product is illustrated in Figure 2.

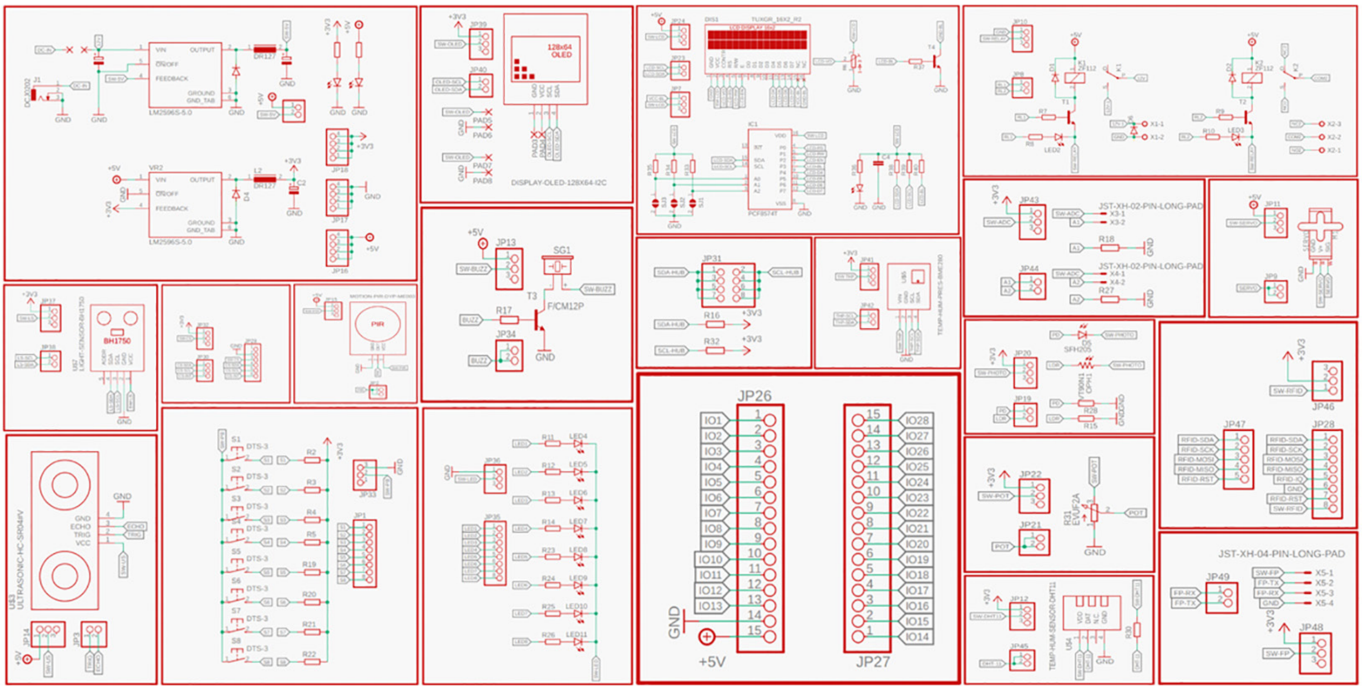

Fig. 2. Schematic circuit of the Internet of Things trainer Kit

After the planning phase of the design, the next step involves fabricating the IoT trainer kit media. This process involves PCB printing and the transfer of pre-made designs onto PCBs. The etching process and removal of the photoresist layer are carried out to create an electrical path pattern that matches the initial design.

Component installation was the next step, which included input blocks with various sensors, process blocks with a NodeMCU ESP8266 microcontroller and mini breadboard, output blocks with an OLED display, relay, active buzzer, and servo motor, and power supply blocks with power modules that provide 5V and 3.3V DC voltage supply. The arrangement of PCBs and components on the trainer box is done carefully to ensure accessibility and an ergonomic layout.

The next step is component testing to ensure optimal quality and performance. Testing is conducted on the input block to verify the response of each sensor to environmental conditions and the accuracy of the resulting measurements. The process block is tested to ensure its ability to properly control and process data, while the output block is tested to ensure that each component provides the expected output. Testing the power supply block involves verifying the stability of the voltage supply by checking the power module. The result of this development stage is an IoT trainer kit that not only functions electronically but also provides a structured and easy-to-understand display.

The final product, a microcontroller-based IoT media trainer kit designed in Figure 2, is depicted in Figure 3.

Fig. 3. Results of making a media trainer

Through a series of detailed and planned steps, this product is prepared for use in a variety of learning activities or IoT experiments. In addition, supporting modules such as usage guides, software installation, basic theory, and sensor and actuator access guides become integral parts that provide comprehensive support for trainer kit IoT media users. The supporting module of the IoT trainer kit is visible in Figure 4.

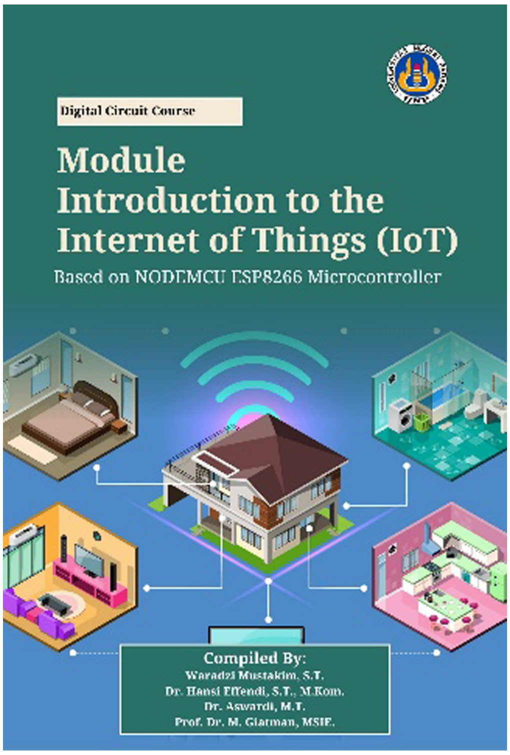

Fig. 4. Trainer kit support module

3.3 Results of the assessment stage (evaluate)

This study involves multiple assessment phases, including the validation of research instruments, media validity, practicality, and effectiveness of the IoT trainer kit learning media. The research instruments' validity, which includes media and practicality assessments, underwent scrutiny by validators and successfully met the established validity criteria. The outcomes of this evaluation are detailed in a table, presenting Aiken's V values and categorizations for instrument validity, which include media expert validation, material expert validation, lecturer practicality, and student practicality. The findings from the instrument validation process are outlined in Table 4.

Table 4. Instrument validation results

Instrument	Validation Results	Category
Media Expert Validation	0.92	Valid
Material Expert Validation	0.71	Valid
Lecturer Practicality	0.83	Valid
Students Practicality	0.83	Valid

Table 4 indicates that the instruments used to assess the validity of both media and materials, as well as the practicalities evaluated by lecturers and students, are considered valid. The instruments assessed by media experts achieved an Aiken V value of 0.92, placing them in the valid category. On the other hand, the instruments evaluated by material experts obtained a validity value of 0.71, also classifying them as valid. Furthermore, the practicality instrument assessed by lecturers obtained an Aiken's V value of 0.83 in the valid category, and the practicality instrument assessed by students received a validity value of 0.83, also classified as valid.

After confirming the validity of the instruments, the next step involves validating the media and materials included in the IoT trainer kit. The media validation questionnaire was administered to two media expert validators and two material experts. They evaluated the content, objectives, instructional aspects, and technical components of the IoT media trainer kit. The results obtained from each aspect assessed by the validators were subjected to analysis using Aiken's V statistical formula. These findings contribute to the validation of the resulting IoT media trainer kit, and a summary of the validation outcomes from various aspects is presented in Table 5.

Table 5. Media validation results

Validator	Validation Results	Category
Media Expert	0.93	Valid
Material Expert	0.86	Valid

According to the findings presented in Table 5, the validity test analysis conducted by media experts yielded an average score of 0.93. This indicates that the IoT media trainer kit falls within the category of validity. Additionally, the validation results from material experts produced an average score of 0.86, confirming the validity of the content within the supporting module for the IoT media trainer kit.

The validation outcomes of this study align with the research conducted by [27], where they developed learning materials for a remote switch control system based on the IoT. In that study, the validity test results from media expert validation showed a percentage of 98.33% with valid qualifications, while material expert validation resulted in a percentage of 96.36% with valid qualifications. This consistency was also observed in the research [28], which focused on developing sensor media trainers. The material expert validation test yielded a percentage result of 83.33% with highly feasible qualifications, while the media expert validation test resulted in 100.00% with very commendable qualifications.

In summary, the assessments from both material experts and learning media experts confirm the validity of the developed trainer. Consequently, it can be inferred that the microcontroller-based IoT trainer kit meets the criteria for content quality, objectives, instructional design, and technical aspects, rendering it suitable for use in lectures to attain learning objectives.

Even though the developed trainer has been declared valid, this product is certainly not free from shortcomings. The module supporting tool use does not provide detailed explanations of the steps for using the tool. The microcontroller-based IoT trainer kit that has been developed is not yet accompanied by complete integrated circuit specifications, and there are still shortcomings in long-term implementation.

Practicality test data for a microcontroller-based IoT trainer kit as a learning tool in the digital circuits course was collected through a questionnaire distributed to six course lecturers and 37 students. The results of the assessment of the practicality of the microcontroller-based IoT media trainer kit are summarized in Table 6.

Table 6. Media practicality results

Respondents	Practicality Results (%)	Category
Lecturer	87.31	Very Practical
Students	83.25	Very Practical

According to the findings presented in Table 6, the practicality test results for the microcontroller-based IoT media trainer kit, based on data from both lecturers and students, show scores of 87.31% and 83.25%, respectively, categorizing it as "very practical" for educational purposes. Consequently, it can be inferred that the microcontroller-based IoT media trainer kit is highly practical for integration into the learning process.

These practicality test results align with a study conducted [29]. In that research, the experimental sheet, module performance, and trainer kit media achieved average performance values of 85.62%, 83.75%, and 85.3%, respectively. This indicates the feasibility and practicality of using the IoT-based microcontroller trainer kit as a learning resource.

In summary, assessments from both lecturers and students indicate that the developed microcontroller-based IoT trainer kit is practical for digital circuit lectures, meeting the four practicality criteria. This suggests that practical trainers facilitate learning for both teachers and students.

The effectiveness of the IoT trainer kit learning medium is demonstrated by its ability to engage students in learning, enhance comprehension of learning material, and improve student learning outcomes. The evaluation of effectiveness involved calculating pretest and posttest data, and the results of the gain score analysis are presented in Table 7.

Table 7. Media effectiveness results of gain score values

N	Min Value (%)	Max Value (%)	Average	Category
37	50	94.12	77.25	Effective

Based on the gain score values presented in Table 7, an average learning outcome of 77.25% was achieved, categorizing the IoT media trainer kit as effective for use as a learning tool. The research and development outcomes of this learning medium align with similar studies conducted by researchers [30] and [22]. In the study by [30], their research on media validation resulted in a "very feasible" assessment with an 80% rating, and user practicality scored 76, falling into the "effective" category. The trainer's effectiveness was confirmed with an "effective" score obtained from the n-gain calculation, which amounted to 0.76.

Similarly, the research [22] focused on developing a media trainer for microprocessor system practice courses, emphasizing user-friendly design. Their research indicated that the trainer's validity was 88%, placing it in the valid category. The Practicality Test showed an average score of 86%, indicating practical usability. In a limited trial with 16 students, the cognitive assessment percentage reached 92%. Consequently, the trainer was deemed valid, practical, and effective.

The collective findings of this research and related studies emphasize that the microcontroller-based IoT trainer kit learning media can be adapted for use in various courses. Therefore, it can be concluded that this trainer kit is a valid, practical, and effective learning tool suitable for the digital circuits courses in Semester 3 of the Electrical Engineering Study Program at the Faculty of Engineering, Muhammadiyah University of West Sumatra.

4 CONCLUSION

Aligned with research goals in educational development, which aim to create educational products effectively utilized in academic settings, this study has successfully generated educational content in the form of an IoT trainer kit tailored for the digital circuit course. Through an analysis of data on the validation, practicality, and effectiveness of the developed IoT trainer kit, it can be affirmed that the product falls within the valid category. The average percentage obtained is significantly high, indicating the fulfillment of content and purpose components as well as instructional and technical aspects crucial for learning media.

Post-product and usage trials, the IoT trainer kit learning media proves highly practical, earning a rating in the "very practical" category. Consequently, it can be asserted that the learning media are exceptionally practical, meeting criteria such as user friendliness, time efficiency, ease of interpretation, and equivalence.

Moreover, the IoT trainer kit learning materials demonstrate effectiveness, as evidenced by the student knowledge test results during the product trial and usage trial stages. The gain score percentage falls within the effective category, substantiating the conclusion that the IoT trainer kit learning medium is proficiently employed as an effective learning tool in the digital circuit course.

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6 REFERENCES

[1] C. Knoblauch, "Combining and balancing project-based and blended learning in education," *International Journal of Advanced Corporate Learning*, vol. 15, no. 1, 2022. https://doi.org/10.3991/ijac.v15i1.27135

[2] Y. Huda, E. Tasrif, F. M. Saragih, W. Mustakim, and N. Vebriani, "Meta analisis pengaruh media e-learning terhadap hasil belajar pada pendidikan kejuruan," *Journal on Education*, vol. 5, no. 2, pp. 2808–2820, 2023. https://doi.org/10.31004/joe.v5i2.929

[3] M. Giatman, I. N. Nafsiah, F. Rizal, and A. Leonardo, "Needs analysis pedagogy project management of technology and vocational educational with the approach of project base learning in higher education," *Journal of Physics: Conference Series*, vol. 1387, p. 012066, 2019. https://doi.org/10.1088/1742-6596/1387/1/012066

[4] A. Abulibdeh, E. Zaidan, and R. Abulibdeh, "Navigating the confluence of artificial intelligence and education for sustainable development in the era of industry 4.0: Challenges, opportunities, and ethical dimensions," *J. Clean Prod*, vol. 437, p. 140527, 2024. https://doi.org/10.1016/j.jclepro.2023.140527

[5] W. Hadi *et al.*, "Enhancement of students' learning outcomes through interactive multimedia," *International Journal of Interactive Mobile Technologies*, vol. 16, no. 7, 2022. https://doi.org/10.3991/ijim.v16i07.25825

[6] A. Wali and A. Popal, "The emerging issues and impacts of technology in classroom learning," *International Journal of Emerging Technologies in Learning (iJET)*, vol. 15, no. 15, pp. 237–245, 2020. https://doi.org/10.3991/ijet.v15i15.14175

[7] Z. Azhar, K. Rukun, J. Jama, H. Effendi, and M. Muskhir, "Effectiveness of e-learning approach to contextual teaching and learning in improving students' Ability," *Journal of Physics: Conference Series*, p. 012110, 2021. https://doi.org/10.1088/1742-6596/1783/1/012110

[8] M. L. Hamzah, F. Rizal, and W. Simatupang, "Development of augmented reality application for learning computer network device," *International Journal of Interactive Mobile Technologies*, vol. 15, no. 12, 2021. https://doi.org/10.3991/ijim.v15i12.21993

[9] A. Andrian, G. Ganefri, and S. Sukardi, "Validity trainer tool as learning media for electric power distribution system," *Jurnal Pendidikan Teknologi Kejuruan*, vol. 3, no. 3, 2020.

[10] Hariyadi, K. Handoko, and A. Noviliza, "The influence of information technology and communication advancement especially smartphone on muhammadiyah university of west sumatera's students year 2019," *Journal of Physics: Conference Series*, p. 012083, 2021. https://doi.org/10.1088/1742-6596/1779/1/012083

[11] R. Mulya, N. Jalinus, and H. Effendi, "Practical work of digital system course based on virtual laboratory," *International Journal of Online & Biomedical Engineering*, vol. 17, no. 8, 2021. https://doi.org/10.3991/ijoe.v17i08.23359

[12] A. Nathoo, G. Bekaroo, T. Gangabissoon, and A. Santokhee, "Using tangible user interfaces for teaching concepts of internet of things: Usability and learning effectiveness," *Interactive Technology and Smart Education*, vol. 17, no. 2, pp. 133–158, 2020. https://doi.org/10.1108/ITSE-09-2019-0061

[13] D. Urbano, M. de Fátima Chouzal, and M. T. Restivo, "Evaluating an online augmented reality puzzle for DC circuits: Students' feedback and conceptual knowledge gain," *Computer Applications in Engineering Education*, vol. 28, no. 5, pp. 1355–1368, 2020. https://doi.org/10.1002/cae.22306

[14] J. Hu, "Teaching evaluation system by use of machine learning and artificial intelligence methods," *International Journal of Emerging Technologies in Learning (iJET)*, vol. 16, no. 5, pp. 87–101, 2021. https://doi.org/10.3991/ijet.v16i05.20299

[15] S. Bourdeau, T. Coulon, and M.-C. Petit, "Simulation-based training via a 'Readymade' virtual world platform: Teaching and learning with minecraft education," *IT Prof.,* vol. 23, no. 2, pp. 33–39, 2021. https://doi.org/10.1109/MITP.2021.3062935

[16] R. Tangking, "The use of internet of things (lot) to produce trainer and remote lab learning media," *Journal of Physics: Conference Series*, p. 012003, 2021. https://doi.org/10.1088/1742-6596/1810/1/012003

[17] J. Q. Kadhim, I. A. Aljazaery, and H. T. H. S. ALRikabi, "Enhancement of online education in engineering college based on mobile wireless communication networks and IoT," *International Journal of Emerging Technologies in Learning (Online)*, vol. 18, no. 1, p. 176, 2023. https://doi.org/10.3991/ijet.v18i01.35987

[18] M. Z. Chaari and S. Al-Maadeed, "Increase the efficiency of iot devices by using the wireless power transmission in the industrial revolution 4.0," *International Journal of Online & Biomedical Engineering*, vol. 17, no. 7, 2021. https://doi.org/10.3991/ijoe.v17i07.24143

[19] M. F. M. Sam, A. F. M. F. Ismail, K. A. Bakar, A. Ahamat, and M. I. Qureshi, "The effectiveness of IoT based wearable devices and potential cybersecurity risks: A systematic literature review from the last decade," *International Journal of Online and Biomedical Engineering*, vol. 18, no. 9, pp. 56–73, 2022. https://doi.org/10.3991/ijoe.v18i09.32255

[20] O. C. Aswardi, A. A. Zoni, and S. Islami, "Development of media trainer motor control fault simulation for electromagnetic control system course," *Article in International Journal of Scientific & Technology Research*, vol. 9, p. 2, 2020.

[21] A. Aswardi, Pd. T. P. Yanto, C. Dewi, H. Zaswita, M. Kabatiah, and R. Kurani, "Human machine interface-based control training kit as innovative learning media to enhance students' automation control skills in the industry 4.0 era," *TEM Journal*, vol. 12, no. 4, 2023. https://doi.org/10.18421/TEM124-26

[22] P. C. Doanwilmon and A. Aswardi, "Pengembangan Media Pembelajaran Mikrokontroler Berbasis Trainer Pada Jurusan Teknik Elektro Fakultas Teknik Universitas Negeri Padang," *JTEV (Jurnal Teknik Elektro dan Vokasional)*, vol. 6, no. 1, pp. 271–276, 2020. https://doi.org/10.24036/jtev.v6i1.107972

[23] T. D. Little *et al*., "The retrospective pretest–posttest design redux: On its validity as an alternative to traditional pretest–posttest measurement," *Int J Behav Dev*, vol. 44, no. 2, pp. 175–183, 2020. https://doi.org/10.1177/0165025419877973

[24] I. Irsyadunas, T. Mary, A. Maizeli, and R. Lina, "Pengembangan Media Pembelajaran Pemahaman Sintak Model Pembelajaran Abad 21 Berbasis Mobile," *J. Ris. Fis. Edukasi dan Sains*, vol. 8, no. 1, pp. 46–59, 2021. https://doi.org/10.22202/jrfes.2021.v8i1.4845

[25] A. Rukajat, *Pendekatan Penelitian Kuantitatif: Quantitative Research Approach*. Deepublish, 2018.

[26] N. A. Handoyono, "Development of media trainer kit charging system to improve effectiveness automotive electrical practices," *VANOS Journal of Mechanical Engineering Education*, vol. 4, no. 2, 2019. http://dx.doi.org/10.30870/vanos.v4i2.6413

[27] G. Y. A. Parawansa, I. G. Ratnaya, and I. G. M. S. B. Pracasitaram, "Media Pembelajaran Sistem Kendali Pensaklaran Jarak Jauh berbasis IoT di Prodi S1 Pendidikan Teknik Elektro Undiksha," *Jurnal Pendidikan Teknik Elektro Undiksha*, vol. 11, no. 3, pp. 132–140, 2022. https://doi.org/10.23887/jjpte.v11i3.50354

[28] G. B. Astrawan, A. Adiarta, and I. G. Ratnaya, "Pengembangan trainer sensor berbasis arduino sebagai media pembelajaran pada mata kuliah mikrokontroler," *Jurnal Pendidikan Teknik Elektro Undiksha*, vol. 9, no. 3, pp. 223–231, 2020. https://doi.org/10.23887/jjpte.v9i3.23668

[29] A. A. N. Fadhilah, A. I. Agung, and N. Kholis, "Pembuatan media pembelajaran trainer mikrokontroller arduino uno berbasis IOT," *Jurnal Pendidikan Teknik Elektro*, vol. 13, no. 1, pp. 21–30, 2023. https://doi.org/10.26740/jpte.v13n01.p21-30

[30] N. Supriyana, E. Permata, and M. Fatkhurrokhman, "Pengembangan media pembelajaran trainer mikrokontroller atmega 16 di program studi pendidikan vokasional teknik elektro," *Jurnal Taman Vokasi*, vol. 7, no. 2, pp. 150–158, 2019. https://doi.org/10.30738/jtv.v7i2.6316

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