Development of Digital Electronics Lab Kit for Vocational Education

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ABSTRACT
Practical application in vocational education must complement theoretical understanding. Experience is essential to understanding and applying digital electronics fundamentals. This project developed a vocational education student-friendly digital electronics lab kit. Students learn digital circuits and logic gates through hands-on exercises in the lab kit. ADDIE guided development. The approach included a thorough analysis of the targeted learners and their educational needs, construction of the laboratory equipment and resources, kit production, and a trial run with a cohort of students. The equipment was then tested in vocational education. The study found that the digital electronics laboratory kit improved students' digital electronics knowledge. Thus, vocational education values it.

Keywords: *Lab Kit, Digital Electronics, Teaching and Learning, Hand-on Experience.*

1. INTRODUCTION

The term "vocational education" refers to a sort of specialized education that places an emphasis on providing students with the information as well as the hands-on skills that are necessary to flourish in particular professions or crafts. Competency-based education is designed to prepare students for specific industries or fields by equipping them with the necessary skills and knowledge to perform job-related tasks and responsibilities [1]. Vocational education classes are available in various fields, including healthcare, technology, construction, manufacturing, and more. [2].

Incorporating experiential learning opportunities such as hands-on training, internships, and apprenticeships is a widely adopted practice in professional education programs. This approach enables students to gain practical experience and develop skills relevant to their chosen field [3-4]. The primary objective of vocational education is to equip students with the requisite knowledge and competencies to excel in their preferred profession while also contributing to the growth of the economy [5].

Hands-on practice is very important in vocational education. Students can put what they've learned in the classroom to use in the real world and learn the skills they'll need to be successful in their chosen field [6-7]. Hands-on training in vocational education can come in many different forms, such as lab experiments, simulations, internships, and apprenticeships [8-9].

Hands-on training in a digital electronics lab is important because it helps students learn important skills, like how to solve problems, think critically, and work with others. It prepares students for a successful career in the digital electronics industry by providing them with applicable real-world experience.

There is a lack of digital electronics lab kits specifically intended for vocational education students [10-13]. While there are numerous lab packages on the market, the majority of them are pricey and may not be affordable for all vocational education programs. As a consequence, many students in vocational education may not have access to hands-on training in digital electronics, which can limit their educational and professional opportunities.

This deficiency would be remedied and the teaching and learning of digital electronics in vocational education programs would be enhanced through the creation of an

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affordable, accessible, and beginner-friendly digital electronics lab equipment.

The current study outlines the creation of a digital electronics laboratory kit with the aim of augmenting the pedagogical experience of vocational education learners. The laboratory kit offers a set of empirical exercises that enable students to acquire practical skills in the realm of digital circuits and logic gates. The instructional design process adhered to the ADDIE model, which comprises five stages: Analysis, Design, Development, Implementation, and Evaluation. The selection of this particular model was made with the intention of providing guidance for the development process, given its systematic nature and widespread use in the field of instructional design. A pilot study was conducted to assess the efficacy and usability of the laboratory kit, which involved students in vocational education..

2. DIGITAL ELECTRONICS COURSE

Digital electronics is an electronics engineering course on digital circuits and systems. Digital circuits, logic gates, Boolean algebra, sequential circuits, and memory devices are covered in this e-learning module. It also discusses component design. Microprocessors, microcontrollers, and digital signal processing are used in the course [14, 15].

Digital electronics courses teach students how to create and develop digital systems, which are the building blocks of modern computers [16]. People who want to design and build digital systems for a living and are interested in electronics, computer engineering, and other related areas should take this course.

The digital electronics lesson has a lab component to help students learn by doing and to repeat what they have learned in the classroom. Students can create, build, test, and fix problems with digital circuits and systems in the lab. Logic gates, combinational and sequential logic, flip-flops, counters, shift registers, and memory devices [17-19] are often covered in lab experiments.

In a digital electronics course, the learning outcomes of a digital electronics lab may rely on the course's specific goals and objectives [20, 21]. However, some common learning outcomes may include:

1. Understanding the fundamental concepts of digital electronics, such as logic gates, Boolean algebra, and binary arithmetic.
2. Gaining hands-on experience with digital electronics components and equipment, such as breadboards, resistors, capacitors, and integrated circuits.
3. Developing practical skills in designing and building digital circuits for specific applications, such as counters, timers, and sequential logic circuits.
4. Learning how to use digital electronics tools, such as oscilloscopes, signal generators, and logic analyzers, to test and troubleshoot digital circuits.
5. Developing critical thinking and problem-solving skills through the process of designing and debugging digital circuits.

3. METHODOLOGY

The development of the digital electronics lab kit involved several stages, including a Analysis, Design, Development, Implementation, and Evaluation. This stage was known the ADDIE model [22]. The ADDIE model for digital electronics lab kit can be shown in Figure 1.

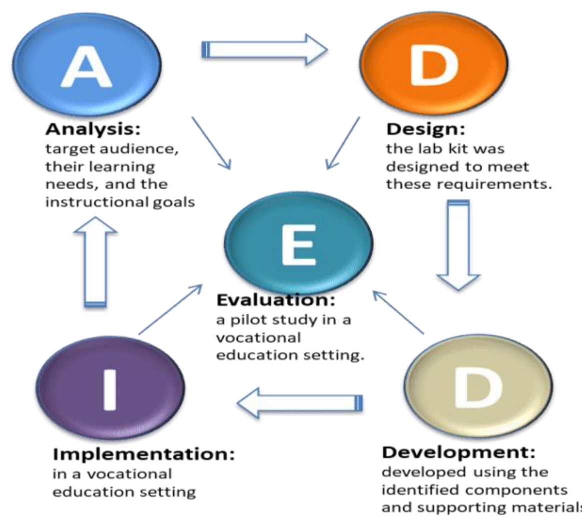

Figure 1 The ADDIE model for the proposed lab kit.

The ADDIE model for each stage is described as follows:

Analysis: To identify the target audience, their learning needs, and the instructional goals of the lab kit the analysis involved interviewing students and teachers in vocational education programs to identify their needs and expectations. The questions asked during the interviews focused on the students' experience with digital electronics, their expectations from a lab kit, and their preferences for the kit's features.

Design: The design of the kit was based on the needs analysis results, and the components were selected to provide a range of practical experiments. The kit included a board, resistors, capacitors, logic gates, LEDs, and other components necessary for building digital circuits. The design of the lab kit included the development of supporting materials such as manuals and guides to provide step-by-step instructions for conducting practical experiments. effectively. The Figure 2 is the design of digital electronics lab kit for basic gates and flip-flop hand-on experience, while in Figure 3 is shown the design for shift register and counter lab kit.

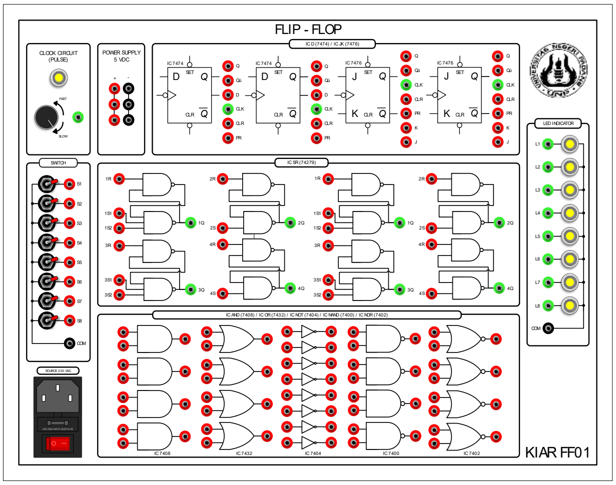

Figure 2 The design for basic gates and flip-flop.

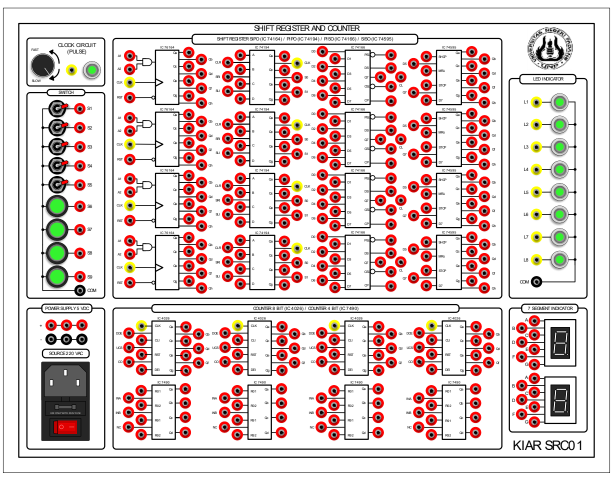

Figure 3 The design for shift register & counter.

Development: After the lab kit was designed, it was developed using the identified components and supporting materials. The ADDIE model's methodical and organized approach was utilized in the development of the laboratory kit, with each stage progressing from the preceding one. The development process followed an iterative approach, whereby feedback was integrated at every stage to ensure that the laboratory kit aligned with the learning requirements and instructional objectives identified during the analysis phase.

Figure 4 depicts the digital electronics lab kit that has been developed to provide practical exposure to fundamental gates. Additionally, Figure 5 showcases the lab kit for shift registers and counters that has been developed.

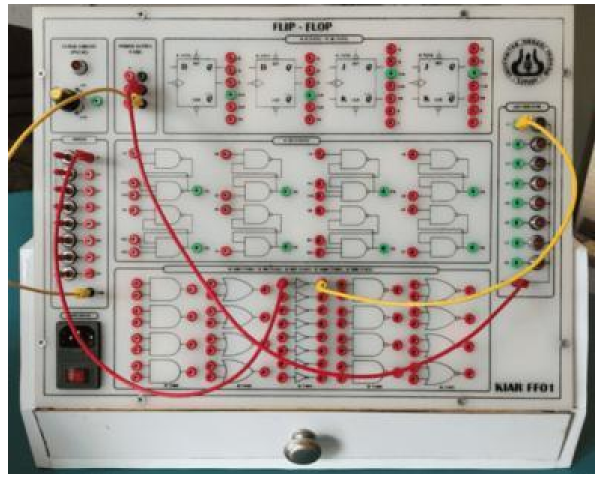

Figure 4 The developed basic gates lab kit.

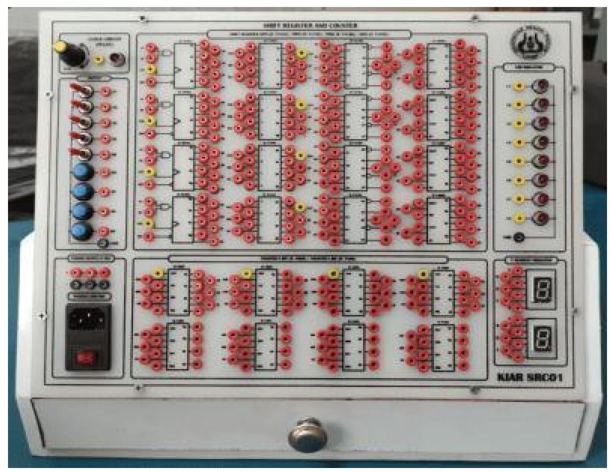

Figure 5 The developed shift register & counter lab kit.

Implementation: The lab kit was used in a professional education setting to see how well it helped students learn more about digital electronics. The lab kit was included in the program for vocational education, and students were given the help and materials they needed to use it well.

The digital electronics lab kit has been implemented and tested in two vocational high schools, namely at SMKN1 Sutera, Kabupaten Pesisir Selatan as shown in Figure 6 and SMKN 1 Sungai Limau, Kabupaten Padang Pariaman as shown in Figure 7.

Evaluation: To evaluate the usability and effectiveness of the lab kit, a pilot study was conducted involving vocational education students. Ten students from a college of technology participated in the pilot project. The lab equipment was made available to the pupils, and they were tasked with conducting a number of experiments. After finishing the lab work, the students were given a survey to fill out in order to provide feedback on the quality of the lab equipment.

Figure 6 Implementation in SMKN 1 Sutera Pessel.

Figure 7 Implementation in SMKN 1 Sungai Limau.

A questionnaire structured along the lines of a 5-point Linkert scale was utilized in the process of assessing the Digital Electronics Lab Kit. Descriptive statistics will be used to conduct the analysis of the data acquired from the survey. The specifics of the survey questions are laid forth in Table 1, which is presented to the respondents.

Table 1. List of Questionnaires.

Q1	The lab kit provided clear and understandable instructions for the digital electronics experiments.
Q2	The lab kit improved my understanding of digital electronics concepts.
Q3	The lab kit provided a good balance of theoretical knowledge and practical skills
Q4	The lab kit was easy to use and navigate.
Q5	The lab kit improved my problem-solving skills in digital electronics.
Q6	The lab kit effectively prepared me for future careers in digital electronics.
Q7	Are you satisfied with the Digital Electronics Lab Kit for Vocational Education?

4. RESULTS AND DISCUSSION

The evaluation of the impact of the Digital Electronics Lab Kit implementation was conducted based on the feedback obtained from the survey. The data obtained from feedback has been subjected to processing and subsequently represented in graphical form, as demonstrated in Figure 8 of this particular study. The survey data was analysed through the examination of questionnaires distributed to respondents. In response to the first query (Q1), it was found that 1% of the participants expressed a strong disagreement, 3% expressed a disagreement, 12% remained neutral, 63% expressed an agreement, and 21% expressed a strong agreement. The findings indicate that a significant proportion of participants concurred that the laboratory kit furnished lucid and comprehensible directives for the digital electronics investigations. The data reveals that the question received a mean score of 4.51 out of 5, which suggests a significant level of consensus among the participants. The data indicates that the laboratory kit effectively facilitated the delivery of pedagogical resources that were comprehensible and user-friendly for the vocational education learners who were exposed to it.

In regards to the second query (Q2), the data indicates that a small proportion of respondents, specifically 2%, expressed a strong disagreement while 6% of respondents disagreed. About 57% of those who answered agreed with the question, and 17% of those who answered strongly agreed. The last 18% of people who answered were not sure how they felt about the question. The data shows that a large number of users thought the lab kit helped them understand digital electronics better. This question's average score of 4.68 out of 5 was the best of all the poll questions. The data shows that the subjects were mostly in agreement about how well the lab kit helped them understand the basic ideas of digital electronics. The result shows that the teaching tools provided by the lab equipment were effective in giving students a hands-on, interesting learning experience that helped them get a deeper understanding of digital electronics principles.

In response to the third question (Q3), it's interesting to note that 1% of the people said they strongly disagreed, while 4% said they didn't agree. Also, 15% of the people who answered were not sure, and 65% of the people who took part agreed with the statement. Last, 15% of those who answered agreed with the statement very much. All of the participants agreed that the lab kit was a good balance between knowing the big picture and getting better at doing things yourself. The fact that the average score for this question was 4.41 out of 5 shows that there was a lot of agreement among the participants. The results show that the lab kit's instructional materials did a good job of combining theoretical knowledge with building real skills. This is crucial for vocational education students to acquire the requisite knowledge and skills for their future professions. The outcome serves as evidence of the ADDIE model's efficacy in creating the lab kit, as it facilitated the incorporation of both theoretical and practical elements in the educational resources.

In response to query four (Q4), it is noteworthy that 3% of the participants expressed a strong disagreement, while 8% of the respondents disagreed. A significant proportion of the participants, that is, 20%, adopted a neutral stance. On the other hand, the majority of the respondents, that is, 54%, agreed with the statement, whereas 15% of the participants strongly agreed. According to the survey results, a significant proportion of participants expressed their concurrence with the notion that the laboratory kit was user-friendly and straightforward to navigate. The data indicates a high level of agreement among the respondents, as evidenced by the mean score of 4.43 out of 5 for this question. This outcome suggests that the laboratory kit was designed with a strong focus on user experience, which is essential for facilitating effective and efficient use by students. The positive results observed in different areas, including improving students' understanding of digital electronics concepts and promoting a balanced combination of theoretical knowledge and practical skills, can be credited to the lab kit's easy-to-use design and navigation.

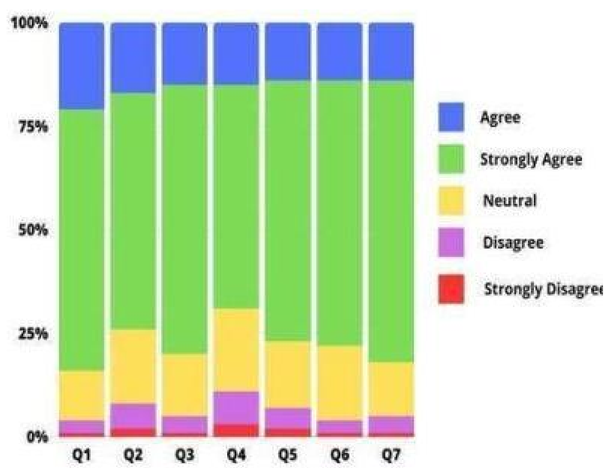

Figure 8 Tabulation of data.

Regarding Q5, it is important to note that a small percentage of the participants (2%) strongly disagreed, while a slightly larger percentage (5%) simply disagreed. 63% of the respondents agreed, with 14% strongly agreeing. It's noteworthy that a significant proportion of 16% of the participants opted to remain neutral when answering the question. According to the survey results, a notable percentage of respondents agreed that the laboratory kit had a beneficial effect on their capacity to resolve issues associated with digital electronics. The data reveals that the question garnered a mean score of 4.25 out of 5, which suggests a significant level of consensus among the participants. The findings indicate that the laboratory kit was efficacious in fostering students' ability to enhance their analytical and critical thinking skills while conducting digital electronics experiments.

In response to question six (Q6), the data indicates that a majority of respondents, specifically 64%, expressed agreement. Additionally, 14% of respondents strongly agreed, while 18% remained neutral. Conversely, a small percentage of respondents, 1% to be exact, strongly disagreed, and 3% expressed disagreement. The findings indicate that a significant proportion of participants (78%) expressed agreement or strong agreement regarding the efficacy of the lab kit in equipping them with the necessary skills for their prospective vocations in the realm of digital electronics. The aforementioned statement implies that the laboratory kit furnished a significant educational opportunity that furnished pupils with the essential knowledge and proficiencies to pursue professions in this domain. The lab kit's efficacy in eliciting a favorable response can be attributed to its comprehensive coverage of digital electronics concepts, emphasis on hands-on experimentation, and prioritization of problem-solving skills development. In summation, it is evident that the lab kit has effectively achieved its intended objective of equipping students with the necessary skills for their future pursuits in the realm of digital electronics.

In response to question seven (Q7), it is noteworthy that 1% of the respondents expressed strong disagreement, while 4% expressed disagreement. A significant proportion of the respondents, specifically 68%, expressed agreement, with 14% expressing strong agreement. The remaining 13% of the respondents expressed neutrality. The findings suggest that a significant proportion of participants (82%) expressed contentment or high levels of contentment with the Digital Electronics Lab Kit designed for Vocational Education. The data indicates that the laboratory kit was positively received by the student population and fulfilled their expectations in regards to substance, ease of use, and efficacy. The favorable outcome may be ascribed to the lab kit's ease of use, the unambiguous and succinct directives, the experiential learning, and the equilibrium between conceptual comprehension and applied proficiencies.

5. CONCLUSION

By adopting the ADDIE paradigm to construct the Digital Electronics Lab Kit for vocational education, it was shown that it was feasible to give students in that field of study hands-on exposure to digital electronics in a practical, affordable, and approachable manner. In order to ensure that the lab kit fits the learning demands of the target audience and accomplishes its educational objectives, the development process was organized and systematic thanks to the usage of the ADDIE model. The lab kit worked well to accomplish these objectives, according to the pilot study. Students' grasp of digital electronics was improved by the lab kit since it was simple to use, interesting, and effective. The lab set was fun for the students to use and they appreciated how useful it was for their vocational education.

AUTHORS' CONTRIBUTIONS

The authors conceived the original idea. All authors discussed and agreed with the main focus and ideas of this paper. Krismadinata contributed to the designing and writing, Irma Husnaini to the implementation, Asnil to the developed assembly, and Hasan Sayuti to the data collection.

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REFERENCES

[1] S. Billett, Learning in the workplace: Strategies for effective practice, Routledge, 2020.

[2] W.G. Ecton & S.M. Dougherty, Heterogeneity in high school career and technical education outcomes, Educational Evaluation and Policy Analysis, 45(1), 2023, pp. 157-81.

[3] B. Brand, A. Valent & A. Browning, How Career and Technical Education Can Help Students Be College and Career Ready: A Primer, College and Career Readiness and Success Center, 2013.

[4] M. Carroll, S. Shaw, & P. Schrader, Virtual reality for career and technical education, Proceeding of E-Learn: World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education, 2019, pp. 1355-1363.

[5] S. Billett, Vocational education: Purposes, traditions and prospects, Springer Science & Business Media, 2011. DOI: https://doi.org/10.1007/978-94-007-1954-5

[6] M.A. Flores, Preparing teachers to teach in complex settings: opportunities for professional learning and development, European Journal of Teacher Education, 43(3), 2020, pp. 297-300.

[7] S. Venkatraman, T. de Souza-Daw, & S. Kaspi, Improving employment outcomes of career and technical education students, Higher Education, Skills and Work-Based Learning, 8(4), 2018, pp. 469-483. DOI: https://doi.org/10.1108/HESWBL-01-2018-0003.

[8] A.Y. Kolb & D.A. Kolb, Experiential learning theory as a guide for experiential educators in higher education, Experiential Learning & Teaching in Higher Education, 1(1), 2017, pp. 7-44.

[9] SS. Budhai, Best practices in engaging online learners through active and experiential learning strategies, Routledge, 2021.

[10] S.C. Mallam, S. Nazir, & S.K. Renganayagalu, Rethinking maritime education, training, and operations in the digital era: Applications for emerging immersive technologies, Journal of Marine Science and Engineering, 7(12), 2019, pp. 428.

[11] D. Mueller & J.M. Ferreira, MARVEL: A mixed-reality learning environment for vocational training in mechatronics, Proceedings of the Technology Enhanced Learning International Conference (TEL 03), 2003.

[12] J.O. Campbell, J.R. Bourne, P.J. Mosterman, & A.J. Brodersen, The effectiveness of learning simulations for electronic laboratories, Journal of Engineering Education, 91(1), 2002, pp. 81-87.

[13] J. Macías-Guarasa, J.M. Montero, R. San-Segundo, A. Araujo, & O. Nieto-Taladriz, A project-based learning approach to design electronic systems curricula, IEEE Transactions on Education, 49(3), 2006, pp. 389-397. DOI: 10.1109/TE.2006.879784

[14] A. Mantri, S. Dutt, J.P. Gupta, & M. Chitkara, Using PBL to Deliver Course in Digital Electronics, Advances in Engineering Education,1(4), 2009.

[15] F.J. Azcondo, A. de Castro, & C. Brañas, Course on digital electronics oriented to describing systems in VHDL, IEEE Transactions on Industrial Electronics, 57(10), 2010, pp. 3308-3316.

[16] E. Todorovich, J.A. Marone, & M. Vazquez, Introducing programmable logic to undergraduate engineering students in a digital electronics course, IEEE Transactions on Education, 55(2), 2011, pp. 255-62. DOI: 10.1109/TE.2011.2169065

[17] C.D. Cunţan, I. Baciu, & M. Osaci, Studies on the Necessity to Integrate the FPGA (Field Programmable Gate Array) Circuits in the Digital

Electronics Lab Didactic Activity, International Journal of Modern Education & Computer Science, 7(6), 2015, pp. 9-15. DOI: 10.5815/ijmecs.2015.06.02

[18] A. Buldu & H.A. Korkmaz, A USB kit for digital I/O applications in a digital electronics lab designed by using PIC16C765 microcontroller, Computer Applications in Engineering Education, 17(2), 2009, pp. 131-138. DOI:10.1002/cae.20172

[19] J. García-Zubía, I. Angulo, L. Rodríguez, P. Orduna, O. Dziabenko, & M. Güenaga, Integration of a remote lab in a software tool for digital electronics, Proceeding of 2013 2nd Experiment@ International Conference, 2013, pp. 174-175.

[20] A.S. Nayak, F.M. Umadevi, T. Preeti, Rubrics based continuous assessment for effective learning of digital electronics laboratory course, Proceeding of 2016 IEEE 4th International Conference on MOOCs, Innovation and Technology in Education (MITE), 2016, pp. 290-295.

[21] S.V. Budihal, N. Patil, S.N. Shashidhar, B. Kinnal, & N.C. Iyer, A blended learning framework for delivery of Laboratory Course in Digital Circuits during COVID-19 pandemic, Proceedings of 2021 World Engineering Education Forum/Global Engineering Deans Council (WEEF/GEDC), 2021.

[22] M.A. Hamid, E. Permata, D. Aribowo, I.A. Darmawan, M. Nurtanto, & S. Laraswati, Development of cooperative learning based electric circuit kit trainer for basic electrical and electronics practice, Journal of Physics: Conference Series, 1456, 2020, pp. 012047. DOI 10.1088/1742-6596/1456/1/012047