Mecha-Learn: Innovative Learning Media for Mechatronics to Improve Technological in the SDGs Era

Jaja Kustia*, Diki Fahrizal, Irgi Surya

Department of Electrical Education, Faculty of Technology and Vocational Education, UPI, Indonesia
*Email: jaja.kustija@upi.edu

ABSTRACT
Increasing technological literacy is very important in the era of the Sustainable Development Goals, because technology plays a role in building a sustainable future. One component SDGs is a terrestrial ecosystem, in the existing conditions learning materials still use a lot of paper materials for practical materials that disrupt terrestrial ecosystems. Mechatronics is a rapidly developing field of technology integrating control, mechanics, electronics and informatics to design sustainable industrial products such as robotics and renewable energy, in which there are components SDGs partnerships to achieve goals. However, learning mechatronics faces challenges such as lack of access to teaching materials, the use of paper which has the potential to increase waste, the limitations of adequate practicum tools, the curriculum which must always be updated according to industrial developments, and the lack of use of technology in learning. The solution offered to overcome this problem is by presenting an interactive and innovative mechatronics learning media website called "*Mecha-Learn*". Mecha-Learn is the latest technology-based interactive learning media for mechatronics. Web-based, Mecha-Learn presents mechatronics content with theory and simulation that is close to the experience of using the original tool. The Mecha-Learn development method follows the ADDIE approach, through focus group analysis, learning design, development, implementation, and evaluation to ensure the quality and appropriate learning needs of mechatronics. This research is expected to make a positive contribution to mechatronic competence and technological literacy as a whole and support the results of SDGs 2030. Mecha-Learn, as a website-based mechatronic learning medium, facilitates access to learning and becomes a new habit according to developments in the industrial society 5.0 era. Mecha-Learn has the potential to become a leading platform in Indonesia that can improve mechatronic learning effectively.

Keywords: *Technology Literacy, Mecha-Learn, Interactive Media Learning, SDGs2030, ADDIE Approach.*

1. INTRODUCTION

Rapid technological advances in the 21st century have changed almost all aspects of life. Starting from how to communicate, work, to the way we go about our daily life routines. In this era of the 2030 sustainable development goals (SDG's), technological literacy plays an important role in empowering individuals and groups to overcome complex global challenges in achieving sustainable development [1], [2]. However, being able to ensure that everyone has the necessary skills and knowledge to navigate and effectively utilize technology is of paramount concern.

Technological literacy includes the ability to understand, evaluate, and use technology to solve problems, communicate, and innovate. It goes beyond technical proficiency and includes critical thinking, digital literacy, and the ability to adapt to ever-evolving technology [3]. In the context of the field of mechatronics, which integrates principles from the fields of mechanical engineering, electrical engineering, and computers, technological literacy is very important [4]. Mechatronics is a field of study that studies the synergistic combination of precision mechanical engineering, electronic control, electronics, informatics in product design from various industries, including manufacturing, robotics, automation and renewable energy, so that individuals who are skilled in the field of mechatronics have the right position to contribute on effort development sustainable [5, 6].

The traditional approach to mechatronic learning tends to be monotonous, only focusing on the theory presented and textbooks, which may not fully engage students or prepare them optimally for real-world applications [7, 8]. To overcome this challenge and increase technological literacy, innovative learning

A. Kusumastuti et al. (eds.), *5th Vocational Education International Conference (VEIC 2023)*,
Advances in Social Science, Education and Humanities Research 813,
https://doi.org/10.2991/978-2-38476-198-2_69

media are needed. This learning media utilizes technology to provide interactive, immersive, and experience-based learning experiences, enabling students to develop a deeper understanding of mechatronic principles and their practical applications[9].

This study presents a new learning media platform called "*Mecha-Learn*" as a website-based mechatronics learning media designed to help students understand the concepts and principles of how tools or components work to approach real objects by using an animation media approach[10]–[12]. The use of animated media in learning has proven to be effective[13], especially in situations where presenting real objects or practicum tools is a challenge in itself. This learning media also offers a solution to overcome the limitations in the availability of real objects or equipment to support mechatronics learning activities which are relatively expensive when viewed from the education budget in developing countries[14]. Along with its development, this learning media has the potential to support the implementation of remote laboratories to overcome the scarcity of inadequate tools and laboratories in various educational institutions across Indonesia[15]. So, it can be a solution for sharing laboratories between institutions or outside institutions in carrying out learning that is carried out in an online embedded system[16], [17].

Several studies related to the development of mechatronics learning media with the animation media approach have been carried out by other researchers. As in the research conducted (Damar AP, Purnawan, and Haipan S)[18], [19], the design of mechatronic learning media is in the form of an application-based android content focused tires with animated media to describe the working principle of pneumatic components with the name "Smart with Pneumatics V.1.0". Besides that, the research conducted (Jaja Kustija and Reni O)[20], designing basic electronics learning media with wordpress-based electronic modules that can be accessed via the website. After looking at the references that have been made by other researchers, in this study an update was made to design a mechatronic learning media model in the form of a website-based platform called "Mecha-Learn (Mechatronics Learning)". The advantage of this research from other studies is that this learning media is designed in the form of platform interactive website-based, more complete content of mechatronics material presented, use of animation media to explain the working principle of approaching the original object, can be accessed by users via computers (PCs) or smartphones so that it can be used flexibly by anyone, anytime, and anywhere, There are several features to support learning, and can be applied for both study groups (at the level of undergraduate, diploma, vocational high school education), or private (private) users.

2. METHOD

The research method uses the Analysis, Design, Development, Implementation, and Evaluation (ADDIE) approach [16, 21]. This research approach is considered suitable for designing and developing learning media used for mechatronic learning [22].

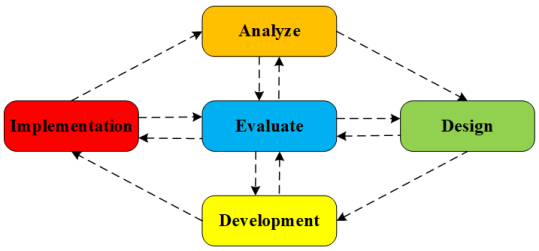

Figure 1 Method Research

Based on Figure 1, the research approach is carried out, the steps taken in this study are through several stages.

The first stage is to identify the needs and objectives of mechatronics learning, analyze the existing mechatronics curriculum, and identify problems and challenges faced in learning which then makes an analysis of website-based mechatronics learning[23].

The second stage is designing a mechatronics learning curriculum by considering the use of technology as a manifestation of digital technology literacy. The third stage is to build and develop a mechatronics learning media platform called Mecha-Learn.*Mechatronics Learning*", develop and test existing learning materials on the platform, then update the Mecha-Learn-based mechatronic learning curriculum.

The fourth stage is implementing solutions by implementing the Mecha-Learn website into mechatronic learning and observing and monitoring the learning process using the Mecha-Learn platform. The fifth stage is to find out the results of learning mechatronics with the Mecha-Learn platform, then evaluating the learning outcomes using the Mecha-Learn platform.

3. OVERALL SYSTEM DESCRIPTION

3.1. Design Results

In an era of rapid technological development, technological literacy has become an important aspect of education. To face this challenge, researchers designed an innovative platform called Mecha-Learn (*Mechatronics-Learning*) which is an interactive learning media platform designed with a focus on mechatronic content. In order to follow the current trend, where every student and learner tends to use smartphones and laptops to search for information, Mecha-Learn is thus designed to be easily accessible through these devices.

Mecha-Learn not only presents theoretical content about mechatronics, but also provides an in-depth understanding of the working principles of mechatronic tools and components with an approach that approaches the working principles of the original object. One of the advantages of Mecha-Learn is the presentation of animations that provide a visual picture of how each mechatronic component works. This helps students to better understand conceptually and practically how these tools operate.

In general, the architecture of the Mecha-Learn system has two main components and one supporting component, namely networking as a link to access the Mecha-Learn website. The two main components in question are the hardware component as a tool for operating the Mecha-Learn website and the software component as the Mecha-Learn website program, whether it's the program data that composes the Mecha-Learn user interface database or the Mecha-Learn website. The overall architecture of the Mecha-Learn website system can be described as follows.

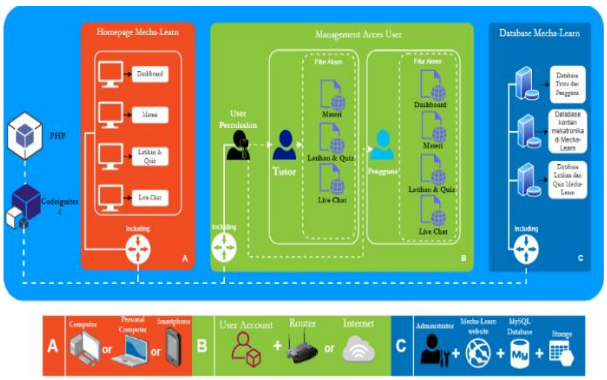

Figure 2 Architecture System Platform Mecha-Learn

Based on Figure 2, it explains that in the Mecha-Learn system there are several parts including a website server that is connected directly to the server as a database. This section is managed by the administrator, then the internet is needed to access the Mecha-Learn website. Users can access the main features on the Mecha-Learn website such as dashboards, materials, and quizzes. There are also additional features to support the learning process such as feature profile and a live chat feature.

Figure 3 Example Content Platform Mecha-Learn

In Figure 3, it is one of the features of the mecha-learn platform that can be accessed by users to understand the working principle of the tool to approach the original object through animated media, besides that there is a live chat feature which will be useful for users to be able to interact with tutors directly via messages.

3.2. Mecha-Learn Access Flow

The Mecha-Learn platform access flow starts with the website interface that users will access. As shown in Figure 4 and Figure 5, the next step after accessing the website interface is to create an account to be able to access the Mecha-Learn platform. Like users, both students and tutors who have accounts are allowed to be able to enter the mecha-learn platform and can use the features available on the platform.

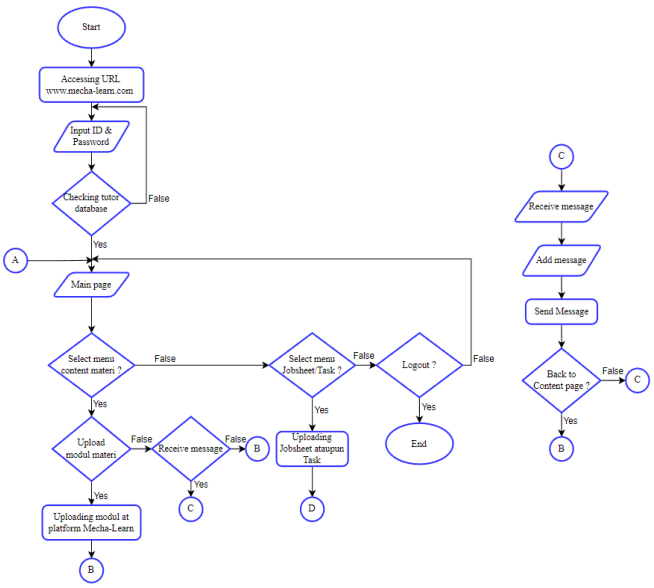

Figure 4 Access Flow Platform for Tutor

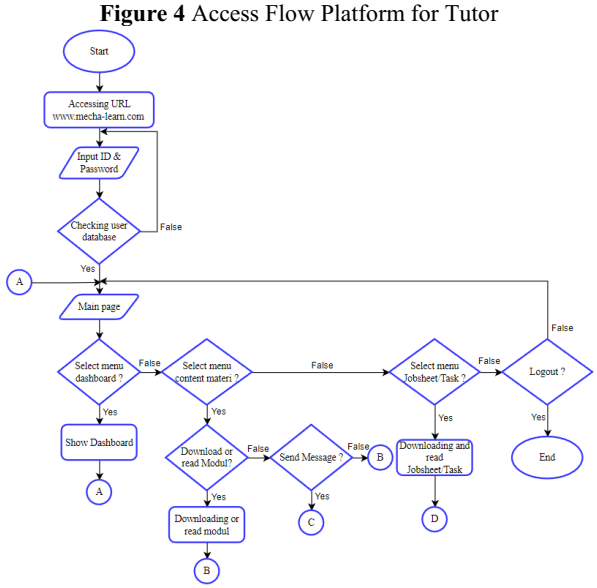

Figure 5 Access Flow Platform for Users

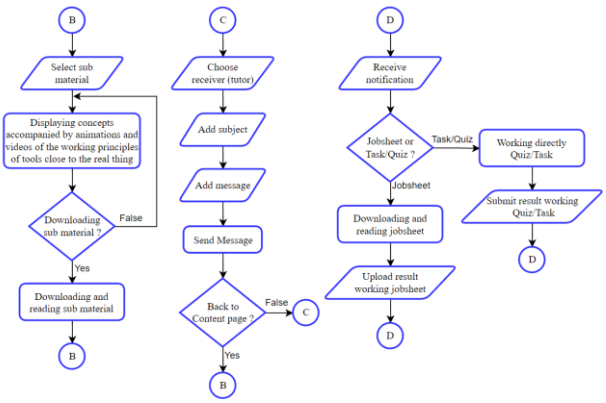

Figure 6 Access Flow Platform for Users (2)

Accessing the Mecha-Learn website for tutors has a separate account that has been verified by the administrator. Accounts that are used other than accounts specifically for tutors, will not be able to access the features available for tutors on the Mecha-Learn platform. Meanwhile, users (students) can be obtained by registering via the platform homepage or through an invite system by tutors, which later students can have access rights to be able to use mecha-learn features for mechatronics learning.

The Mecha-Learn access flow ensures a smooth and interesting learning experience, and students can understand mechatronic concepts with ease and flexibility. By combining interactivity, multimedia, and personalization features, Mecha-Learn can enable students to develop strong technology literacy skills in the digital era of education.

3.3. Mecha-Learn System Settings

In the continuity of the Mecha-Learn platform, there are three main components that play an important role, namely tutors, administrators and users. The role of each of these parties is very important to maintain smoothness and interactivity on the mecha-learn platform.

3.3.1. *Tutor*

The role of the tutor is that of a lecturer/teacher/material expert who has a teaching field or competence in the field of mechatronics. Duties and authorities as a tutor in managing the running of the mecha-learn website between:

- Provide an explanation about the use and how to access the mecha-learn website.
- Management of classroom/study group arrangements.
- Uploading module in the material menu.
- Uploading job sheets or exercises on the exercise/quiz features.
- Check assignments uploaded through the system.
- Answer any questions submitted by students/users through the live chat feature.

3.3.2. *Administrator*

Administrator Represents the party responsible for managing all system requirements so that the Mecha-Learn platform can run interactively and efficiently. They ensure that the platform is continuously updated, managed and improved according to technological developments and user needs. The main duties of an administrator include:

- Management of classroom/study group arrangements.
- Mecha-learn website database management.
- Responsible for the smooth access of the mecha-learn website.
- Overcome problems when accessing the mecha-learn website, such as bug problems.

3.3.3. *User (Student)*

Users are students or students as objects of the study group whose role is very concerned with the running of the mecha-learn website which has the following duties and authorities:

- You can download or study directly without place and time restrictions on the modules/materials on the mecha-learn website
- Work on a job sheet to measure understanding user about mechatronics
- Users can also use the live chat feature available on the mecha-learn website, if there are problems or problems that have not been understood.
- Uploading the assignments provided in each chapter

4. RESULT AND DISCUSSIONS

4.1. Functional Test Platform Mecha-Learn

4.1.1. *Website Quality with ISO/IEC 25010 Standard*

Functional testing of the Mecha-Learn platform was carried out using the ISO/IEC 25010 quality website standard approach by testing several aspects, such as functional suitability, compatibility, maintainability, and usability[24].

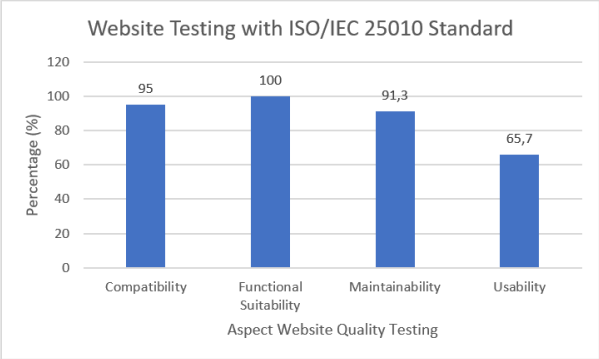

Figure 7 Result Website Testing Quality

4.1.2. *Trial Test*

The following is a data questionnaire obtained from the results of the Mecha-Learn platform design that has been created on the server and accessed by users.

Table 1. Platform Mecha-Learn Evaluation Questionnaire

Q#	Questionnaire	Score				
		5	**4**	**3**	**2**	**1**
Q1	To what extent do you feel that Mecha-Learn learning content is easy to understand?	25	2	3	3	0
Q2	What do you think about the quality of the learning videos provided by Mecha-Learn?	15	10	2	2	4
Q3	How useful are the practice questions provided in Mecha-Learn in increasing understanding of mechatronic content?	18	12	3	0	0
Q4	How often do you visit the discussion forums on Mecha-Learn to interact with other users?	10	15	2	5	1
Q5	How easy is navigation in Mecha-Learn to find the learning materials you need?	20	9	4	0	0
Q6	To what extent do you feel Mecha-Learn helps improve your understanding and skills in the field of mechatronics?	22	5	4	2	0

4.2. Implications of the Mecha-Learn Platform as Educational Technology Literacy

In its implementation, the Mecha-Learn platform has positive implications in increasing educational technology literacy in the field of mechatronics [25]. The mecha-learn platform can help realize the achievements of several aspects of sustainable development such as the fulfillment of quality education; industry, innovation, and infrastructure; terrestrial ecosystems; and partnerships to achieve goals[26]. Following are the implications of the Mecha-Learn platform from each important point as the realization of sustainable development achievements, namely as follows:

*4.2.1. Quality Education **(Point 4)***

The Mecha-Learn platform can provide better accessibility for mechatronics learning to students in various conditions, such as geographical locations or in terms of learning infrastructure. Platform This can be accessed online via smartphones or personal computers, thus overcoming the limitations that allow students from various backgrounds to get quality education in the field of mechatronics[2].

Through the Mecha-Learn platform, it provides opportunities for students to experiment and be creative in mechatronic content. The limitations of presenting components related to mechatronics are very expensive, so the Mecha-Learn platform is a medium with an animated approach to help students become more skilled and increase technological literacy for students.

Platform Mecha-Learn can improve the quality of teaching and learning in mechatronic content. This learning familiarizes students and teachers in the use of the industrial era 4.0 and 5.0 in mechatronics learning. In its implementation, it can integrate the learning modules available on the platform into the learning curriculum at school[2], [27].

*4.2.2. Industry, Innovation, and Infrastructure (**Point 9**)*

Through the Mecha-Learn platform, students can provide access to quality mechatronics education, especially in the isolated regions. This can help them to have the skills they need.

Through this Mecha-Learn platform,participant students can access simulations, visualizations, and interactive learning tools to understand mechatronics concepts properly. This can help build a technology infrastructure that supports effective mechatronics learning[28].

*4.2.3. Terrestrial Ecosystem (**Point 15**)*

Through this Mecha-Learn platform, you can promote environmentally friendly innovations. This is related to the large use of paper media as teaching materials in learning and also component wastes used for practicum often get a little polluted. Through the use of the Mecha-Learn platform, materials used in learning activities such as paper or other practicum materials can be saved and replaced through electronic media.nor virtual [29].

*4.2.4. Partnership to Achieve Goals (**Point 17**)*

Through the Mecha-Learn platform, student teachers, industry and educational institutions can participate in exchanging knowledge regarding mechatronics content, as one of the areas of technology that is being rapidly used, thus encouraging effective collaboration between various parties involved in mechatronics education, creating partnerships strength to achieve common goals [30].

4.3. Analysis of the Mechatronic Learning Approach with the Mecha-Learn Platform

4.3.1. The advantages of Mecha-Learn in mechatronics learning media

There are several advantages of having the mecha-learn website as a mechatronic learning medium, including:

- It can be accessed anywhere at any time via a smartphone/personal computer (PC) as long as it is connected to the internet/intranet.
- Own Feature-important features that can support mechatronic content learning (dashboards, materials, quizzes, live chat)
- Study time is more flexible for both study group users and individuals (private)
- The cost is more affordable, because the procurement of original components related to mechatronics is very expensive
- New content can be developed, such as adding extensions to carry out independent simulations through the Mecha-Learn website
- Can display demos in the form of images, animations, and videos
- Can explain the working principle of the tool close to the real tool

4.3.2. Disadvantages of Mecha-Learn in mechatronic learning media

Besides having advantages, there are also disadvantages of mecha-learn as a mechatronic learning medium, including:

- Not all places have internet facilities (this is related to problems with smartphones, computers, or electricity availability)
- Lack of IT mastery for some people

4.3.3. Mechatronics learning matrix embedded system

The use of the mecha-learn website can also be applied to mechatronic learning at both the Vocational High School level and the Higher Education level. With the mecha-learn website, it can add forms of learning that can be collaborative with other forms of learning. The following mechatronics learning matrix table can be seen in table 2.

Table 2. Mechatronics embedded system learning matrix

No.	Learning Content	Learning Approach	Form of Learning
1.	Theory	Online or Offline	Presentation, discussion, use of Mecha-Learn
2.	Explanation of the principle of how the components work	Online or Offline	Demo of how the tool works, use of Mecha-Learn (animation of how components/tools work)
3.	The combination of components with the system	Online or Offline	Fluidsim software, use of Mecha-Learn (tool working principle animation)
4.	Project	Online or Offline	Combination

5. CONCLUSION

A website-based mechatronic learning media suitability has been designed called the Mecha-Learn (Mechatronics Learning) platform, which presents mechatronics content in the form of brief explanations accompanied by an animated approach that describes how tools or components work to approach the original object with the features presented to help students to explore insights and competencies in the field of mechatronics. Based on the results of the analysis that has been carried out, the Mecha-Learn platform can be implemented in a good Mechatronics both in the higher education level environment and at the lower level. This can be a positive contribution to increasing technological literacy in the field of education as an effort to realize the achievement of one aspect of the goals of sustainable development.

This research produces a mechatronics learning media that can overcome the limited access to expensive practicum components and real objects. This media is a learning innovation that can be accessed anywhere and anytime according to the development of the current era. Apart from that, the existence of the Mecha-Learn platform is one of the efforts to realize several points of sustainable development goals such as the aspect of fulfilling quality education; industry, innovation, and infrastructure; terrestrial ecosystems; and partnerships to achieve goals.

ACKNOWLEDGMENTS

We would like to thank all parties who were actively involved in the continuation of this research, so that the results of this research were as expected. Our thanks also go to the conference organizers who have received the draft of this paper in a good way, so that this research can be used as a reference for other researchers.

REFERENCES

[1] A. Lekan, C. Aigbavboa, O. Babatunde, F. Olabosipo, and A. Christiana. Disruptive technological innovations in the construction field and fourth industrial revolution intervention in the achievement of the sustainable development goal 9," International Journal of Construction Management, vol. 22, no. 14, 2022, pp. 2647–2658. doi: 10.1080/15623599.2020.1819522.

[2] D. Olsson, N. Gericke, and J. Boeve-de Pauw. The effectiveness of education for sustainable development revisited–a longitudinal study on secondary students. Action competence for sustainability. Environ Educ Res, vol. 28, no. 3, 2022, pp. 405–429, doi: 10.1080/13504622.2022.2033170.

[3] X. Liu et al. Understanding vocational accounting students. Attitudes towards sustainable development. Journal of Vocational Education and Training, vol. 74, no. 2, 2022, pp. 249–269, , doi: 10.1080/13636820.2020.1760333.

[4] J. Kustija, I. Surya, and D. Fahrizal. Electrical Energy Savings by Utilizing Internet-based Automatic Monitoring and Control of Things. 2022.

[5] C. Pacher, M. Woschank, and B. M. Zunk. The Role of Competence Profiles in Industry 5.0-Related Vocational Education and Training: Exemplary Development of a Competence Profile for Industrial Logistics Engineering Education. Applied Sciences (Switzerland), vol. 13, no. 5, Mar. 2023, doi: 10.3390/app13053280.

[6] Jaja Kustija, Irgi Surya, and Diki Fahrizal. Design of automated power factor monitoring and repair tool for industry in real time based on Internet of Things. International Journal of Science and Technology Research Archive, vol. 3, no. 2, Oct. 2022, pp. 001–008, doi: 10.53771/ijstra.2022.3.2.0106.

[7] X. Liu et al. Understanding vocational accounting students' attitudes towards sustainable development. Journal of Vocational Education and Training, vol. 74, no. 2, 2022, pp. 249–269, doi: 10.1080/13636820.2020.1760333.

[8] S. Afifah et al. Sustainability Literacy to Vocational Students through Distance Learning with Experimental Demonstration: Ionic Liquid Experiment and Its Application as Fire Retardant. Journal of Technical Education and Training, vol. 15, no. 1, Mar. 2023, pp. 55–72, doi: 10.30880/jtet.2023.15.01.006.

[9] M. A. R. Forhad, G. M. Alam, M. Rashid, A. Haque, and M. S. Khan. Sustainable Development in Higher Engineering Education: A Comparative Study between Private and Public Polytechnics. Sustainability (Switzerland), vol. 14, no. 13, Jul. 2022, doi: 10.3390/su14138094.

[10] M. Garduno-Aparicio, J. Rodriguez-Resendiz, G. Macias-Bobadilla, and S. Thenozhi, "A Multidisciplinary Industrial Robot Approach for Teaching Mechatronics-Related Courses," IEEE Transactions on Education, vol. 61, no. 1, pp. 55–62, Feb. 2018, doi: 10.1109/TE.2017.2741446.

[11] J. Kustija, H. Hasbullah, and Y. Somantri. Design of mechatronic simulators to improve the quality of students learning outcomes in mechatronics subject. in Journal of Physics: Conference Series, Institute of Physics Publishing, Dec. 2019. doi: 10.1088/1742-6596/1402/3/033085.

[12] J. Kustija, Hasbullah, and Y. Somantri. The Design of Mechatronics Simulator for Improving the Quality of Student Learning Course in Mechatronics. in IOP Conference Series: Materials Science and Engineering, Institute of Physics Publishing, Feb. 2018. doi: 10.1088/1757-899X/306/1/012063.

[13] U. Sultan Ageng Tirtayasa. Model pembelajaran pendidikan vokasional yang efektif di era revolusi industri 4.0 Irwanto Irwanto

[14] A. Ana. Trends in Expert System Development: A Practicum Content Analysis in Vocational Education for Over Grow Pandemic Learning Problems. 2020.

[15] V. Wulandary, N. Rizani, R. Nafsi, and R. Maryanti. Analysis of Teacher Skills in E-Learning Content Development during Distance Learning during the Covid-19 Pandemic Science learning for students with autism View project Primary Education Research View project Analysis of Teacher Skills in E-Learning Content Development during Distance Learning during the Covid-19 Pandemic. 2021.

[16] J. Kustija. Solutions to Overcome Inequality in Laboratory Facilities and Laboratory Sharing in Similar Institutions Remote Laboratory based. 2022.

[17] J. Kustija and N. D. Jayanto. IoT Implementation for Development of Remote Laboratory (Case Study on Microscope Practice). Reka Elkomika: Jurnal Pengabdian kepada Masyarakat, vol. 3, no. 1, pp. 20–29, Jan. 2022, doi: 10.26760/rekaelkomika.v3i1.20-29.

[18] D. Aji Pramastiko and H. Salam. Design and Build Learning Media for Pneumatic and Hydraulic Animation ased on Android. 2021.

[19] M. Fakhri Ibrahim and J. Kustija. Implementation of Android-based Media Smart With Pneumatics V.1.0 in Pneumatic Control System Learning. 2021.

[20] J. Kustija and R. Oktadianingsih. Creating E-Modules Basic Electricity And Electronic Courses Based On Wordpress For Vocational School Students. in ISMEE 2021 - 2021 3rd International Symposium on Material and Electrical Engineering Conference: Enhancing Research Quality in the Field of Materials and Electrical Engineering for a Better Life, Institute of Electrical and Electronics Engineers Inc., 2021, pp. 343–347. doi: 10.1109/ISMEE54273.2021.9774144.

[21] J. Kustija, A. Ana, and N. Dwi Jayanto. Web-Based and Thinvnc Remote Laboratory Implementation to Support Students Skills in Mechatronics Course to Face the Industrial Revolution 4.0. 2021.

[22] J. Kustija, D. L. Hakim, and H. Hasbullah Development of Internet of Things (IoT) based learning media in efforts to improve student skills at the industrial revolution era 4.0. in IOP Conference Series: Materials Science and Engineering, Institute of Physics Publishing, May 2020. doi: 10.1088/1757-899X/830/4/042051.

[23] L. A. Pratama and J. Kustija. Design of Graphical User Interface (GUI) on IoT-based remote laboratory for Programmable Logic Controller (PLC) practicum and pneumatic simulation. in IOP Conference Series: Materials Science and Engineering, Institute of Physics Publishing, May 2020. doi: 10.1088/1757-899X/830/4/042053.

[24] D. Fahrizal and J. Kustija. Creating an Innovative Mechatronics Learning Experience with Mecha-Learn: A Website-Based Platform. 2023.

[25] M. A. R. Forhad, G. M. Alam, M. Rashid, A. Haque, and M. S. Khan. Sustainable Development in Higher Engineering Education: A Comparative Study between Private and Public Polytechnics. Sustainability (Switzerland), vol. 14, no. 13, Jul. 2022, doi: 10.3390/su14138094.

[26] O. Legusov, R. L. Raby, L. Mou, F. Gómez-Gajardo, and Y. Zhou. How community colleges and other TVET institutions contribute to the united nations sustainable development goals. J Furth High Educ, vol. 46, no. 1, 2022, pp. 89–106, doi: 10.1080/0309877X.2021.1887463.

[27] D. Olsson, N. Gericke, and J. Boeve-de Pauw. The effectiveness of education for sustainable development revisited–a longitudinal study on secondary students' action competence for sustainability. Environ Educ Res, vol. 28, no. 3, 2022, pp. 405–429, doi: 10.1080/13504622.2022.2033170.

[28] D. Gürdür Broo, O. Kaynak, and S. M. Sait. Rethinking engineering education at the age of industry 5.0. J Ind Inf Integr, vol. 25, 2022, p. 100311, doi: https://doi.org/10.1016/j.jii.2021.100311.

[29] S. Afifah et al. Sustainability Literacy to Vocational Students through Distance Learning with Experimental Demonstration: Ionic Liquid Experiment and Its Application as Fire Retardant. Journal of Technical Education and Training, vol. 15, no. 1, 2023, pp. 55–72, doi: 10.30880/jtet.2023.15.01.006.

[30] C. Pacher, M. Woschank, and B. M. Zunk. The Role of Competence Profiles in Industry 5.0-Related Vocational Education and Training: Exemplary Development of a Competence Profile for Industrial Logistics Engineering Education. Applied Sciences (Switzerland), vol. 13, no. 5, Mar. 2023, doi: 10.3390/app13053280.