Optimization of Gasification Learning in Vocational High Schools using Virtual Laboratories

Gesti Khoirunnisa, Herman Saputro*, and A. G. Tamrin

***Abstract*—A lack of energy-conscious behavior causes wasteful energy use in everyday life. Unfortunately, in Indonesia, energy-conscious behavior is not yet a requirement that must be included in the school curriculum. As a result, not many schools open energy-related classes and teach about energy in Indonesia, even though the Ministry of Education facilitated the establishment of Vocational High Schools (VHS) for energy and mining fields. The slow development of VHS in energy and mining is due to the high cost of procuring laboratory facilities and infrastructure for student practicums. In addition, the lack of supporting equipment in the laboratory causes the learning process in VHS to be theoretical, and the essential competency skills are not optimally fulfilled. This research developed practical energy tools to overcome these problems, especially renewable energy competencies from biomass to energy through gasification. The practicum aid developed is in the form of a Gasification Virtual Laboratory (GVL). This study uses a qualitative method with a case study approach. The case study was selected to develop GVL, which follows the phenomenon of VHS students' learning abilities, especially for students in grade X. GVL development uses a 4-D model (Define, Design, Develop, and Disseminate). The study results show that GVL is feasible and effective in supporting renewable energy learning at VHS. The GVL development results will be discussed in depth in this paper.**

***Index Terms*—Energy education, gasification virtual laboratory (GVL), vocational high school (VHS)**

I. Introduction

The increase in primary energy consumption with fossil fuels is one of the cases faced by almost the entire world. According to Energy Outlook [1], the use of oil, gas, and coal increased by an average of 1.1% p.a. (per annum). For example, in Indonesia, primary energy consumption during 2018-2050 is estimated to grow from 1,504 million barrels of oil equivalent (BOE) to 5,284 million BOE, or an average of 4.2% per year [2]. The increasing world energy demand has become a global problem in various sectors resulting in an energy crisis. Worldwide energy demand has increased, but fossil energy reserves have decreased [3]. Renewable energy sources are a crucial issue because they are cleaner and have a minor environmental impact [4].

Saputro *et al*. [5] experimented with renewable energy, converting palm oil waste as biomass fuel in a gasifier. A gasifier or processing equipment is one of the instruments that can convert biomass into energy. *Gasification* is a thermochemical energy conversion process that utilizes biomass or coal into Syngas. The Syngas contains H_2, CO, and CH_4. Syngas can be used as a power plant and a small-scale gas generator for the combustion of motorized vehicles.

Energy needs in Indonesia in the household sector are dominated by electricity use at 53% and LPG gas at 44% [6]. Therefore, from the order of energy use in Indonesia, renewable energy ranks 3rd after petroleum and coal. However, on the other hand, Indonesia has quite an enormous potential for Renewable Energy, including mini/micro hydro of 450 MW, Biomass 50 GW, solar energy of 4.80 kWh/m^2/day, wind energy of 3-6 m/s and 3 GW of nuclear energy. The renewable energy data is exciting because there are 50 GW of potential biomass in Indonesia. However, one of the obstacles to reaching the renewable energy market is the lack of qualified human resources [7].

The unavailability of human resources has resulted in not being able to utilize the potential of renewable energy in Indonesia. In Indonesia, few schools open classes related to energy and teach about energy. Even though the Ministry of Education and Culture facilitated the establishment of Vocational High Schools (VHS) in the fields of energy and mining. Therefore, it impacts the lack of engineers and technicians related to energy, especially renewable energy [3]. Jennings [8], currently, many engineers are not trained and do not understand the principles of renewable energy technology. Through energy-related education taught in Vocational High Schools that teach planning, development, and processing of renewable energy, it is hoped that it can assist the restructuring process in the energy sector [9].

Energy education is crucial for instilling concern for energy conservation and energy-saving behavior among youth [10]. Energy conservation can be achieved through the habituation of saving behavior, caring attitudes, and energy conservation innovations [10–12], where these behaviors need to be introduced early on. One's energy-saving behavior can lead to energy savings of up to 20% [13]. However, in his research, D. Gervais [11] said that environmentally conscious behavior is still far from achieving energy savings. Thus, it is necessary to understand energy conservation so that users can be wiser and more efficient. Therefore, an understanding of energy can be obtained through energy education.

Acikgoz [14] states that education on renewable energy (REE) is one of the most significant efforts to address energy-related problems in society. Baldur [15] emphasized that education related to renewable energy must be given from a young age. Education about energy can change human behavior to be efficient [16]. Through existing learning, knowledge and behavior regarding renewable energy can be instilled. Knowledge and concern for the environment need

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to be emphasized because they will become the basis for dealing with future energy needs [17]. Incorporating renewable energy materials in the curriculum should inspire and motivate students to better understand and be creative in creating and developing energy sources. Therefore, it is necessary to be equipped with critical, creative, and innovative thinking patterns. According to research by E Wiwin, 2020 [18], in the case of learning physics, there are three kinds of intelligence simultaneously, which include cognitive, psychomotor, and affective.

The three components of intelligence in physics learning, cognitive, psychomotor, and affective, are essential in implementing Renewable Energy Education (REE) in Indonesia. REE material is currently part of the Physics Basic Competence for physics subjects. In these essential competencies, students learn energy and its development material through observation, problem formulation, experiments, conclusions, and the discovery of theories and concepts [19]. Education related to renewable energy can be provided by developing essential competencies [20]. Development can focus on basic competencies in understanding renewable energy in the skills aspect. These skills can be taught through laboratory activities to make students more constructive, think critically, be able to solve problems, and have an investigative approach related to renewable energy. Laboratory activities can be carried out virtually using a Virtual Laboratory (VL) [21]. The development of information and communication technology accommodates new teaching methods. VL has become one means to accommodate the need for information technology-based learning [21]. According to D. Ibrahim, 2010 [22], VL is cheaper and can increase interaction between teachers and students to be a learning solution and maximize student competence achievement.

The laboratory is crucial in learning-oriented toward achieving skills, especially in engineering learning [23]. The high cost of procuring equipment in the energy laboratory allows VL to turn abstract learning into concrete at a low cost. Based on the problem of limited equipment in the energy laboratory, research is necessary to develop VL to support energy learning, especially renewable energy. VL design is made interactively and consists of text, graphics, simulations, and animations [21]. The animations and simulations contained in the VL allow students to interact with materials and equipment [24]. Procurement of laboratory equipment requires high costs, and some schools even lack materials and equipment [25]. The VL development is expected to solve the limitations in procuring expensive laboratory equipment. VL has advantages, including flexibility, practicums can be carried out in a virtual but resembling actual form, and active student learning can be carried out [26, 27]. Some VHS, considering limited equipment, carry out learning only theoretically, so students cannot achieve those core competencies and skills.

This research focuses on energy learning in Vocational High Schools (VHS) in Indonesia because the ministry of education is currently pushing for the opening of VHS, which focuses on energy and mining. Another reason for choosing VHS is that learning focuses 60% on skills and 40% on theory. This learning focus is inversely proportional to learning at the same level, namely Senior High School (SHV) in Indonesia, where SHV has a 60% focus on theoretical strengthening and 40% practicum. Research conducted by Marshal, 2021 [28] in Indonesia VL is effective as a learning medium in VHS because it can bring students closer to actual cases and supports the achievement of student skills. This research focuses on developing renewable energy practicum tools to overcome learning problems, especially the competency of renewable energy from biomass to energy through gasification. The practicum aid developed is in the form of a Gasification Virtual Laboratory (GVL). Furthermore, the GVL product is used as a learning practicum tool in VHS.

II. Methods

This study uses a qualitative method with a case study approach. Case studies were chosen to develop GVL following the phenomenon of the learning abilities of SMK students, especially class X students. The development of GVL uses the 4-D model (Define, Design, Develop, and Disseminate) developed by Thiagarajan [29]. Data collection techniques in this study used interviews and questionnaires. Learning media experts from the Sebelas Maret University learning center validated the virtual laboratory for REE learning practices. GLV problems and needs were carried out through interviews with teachers, students, and school management. The research questionnaire is used to validate the ease and benefits of the application. The data in this study consisted of qualitative data and quantitative data. Qualitative data is the form of interviews and suggestions for media improvement. Quantitative data is used for the average criteria for the development of VL. The sequence of the 4D model carried out in the study can be explained as follows:

A. The Definition Stage (Define)

The definition stage involves: 1) analysis of determining the fundamental problems experienced by students in the learning process; 2) analysis of core competencies and essential competencies based on the curriculum; 3) analysis of the concept, determining the material to be delivered through the media; and 4) analysis of learning objectives, which includes formulating indicators of learning objectives to be achieved.

B. The Design Stage (Design)

The design stage for the virtual gasification laboratory involves 1) preparation of reference tests; 2) media selection which includes determining the suitable media; 3) format selection, which includes choosing the media format, lesson plan, and sources; 4) initial design: the initial design that becomes the guide in the process.

C. The Development Stage (Develop)

The development stage involves: preparing for software and hardware requirements: 1) Adobe AIR SDK, Adobe Animate, and Corel Draw, 2) PC or laptop with a minimum specification of 4096 Mb RAM, Windows 10 Pro-64 bit. The subsequent media making is expert validation: testing the feasibility of media and materials by making improvements. Media and material experts from Universitas Sebelas Maret validate the media and materials produced in stage 1. The instruments used to validate the virtual gasification laboratory are in Table I. The stage of designing a virtual laboratory is created by using animated software.

TABLE I: INSTRUMENTS FOR VALIDATION OF GASIFICATION LABORATORY VIRTUAL MEDIA

Device Display Aspect	Q1	Media development is carried out efficiently and effectively
	Q2	Attractive-oriented virtual laboratory interface
	Q3	The developed media can be used effectively and efficiently
	Q4	Media can be managed or maintained easily
	Q5	Learning media can be operated easily
	Q6	Instructions for use are presented clearly
	Q7	App used right
	Q8	The media developed is free of advertisements, and there are instructions for the use
Visual Aspect	Q9	The choice of letters used is appropriate
	Q10	Selection of appropriate color degradation
	Q11	The layout of the design pattern used is appropriate
	Q12	The image display used is by the material
	Q13	The selection of sound effects used is appropriate
	Q14	The media design is presentable
	Q15	Display layout design with the appropriate character of vocational high school students

D. *The Dissemination Stage (Disseminate)*

The dissemination stage is carried out by spreading the use of media. This stage is the final development stage. This activity is appointed to distribute media for students to facilitate the process of teaching and learning activities. The virtual laboratory was tested at Vocational Schools during the Covid-19 pandemic on a limited scale. The developed virtual laboratory product is conducted with a feasibility test to determine the effectiveness of the virtual laboratory as a learning medium from several vocational schools in Indonesia.

III. RESULT AND DISCUSSION

A. *Need Analysis to Support the Development of a Gasification Virtual Laboratory (GVL)*

In the initial stages, the researchers conducted a needs analysis related to GVL. The needs analysis was carried out to support the development of GVL and to get compatibility with the learning competency targets in VHS. The scope of needs analysis for GVL development includes 1) tool problems in gasification practicum, 2) problems in gasification learning methods, 3) Manpower problems in gasification learning, and 4) material problems in gasification practicum. The data collection method at the needs analysis stage was conducted through interviews with teachers and students at VHS. The results of the analysis that has been carried out can be seen in Fig. 1.

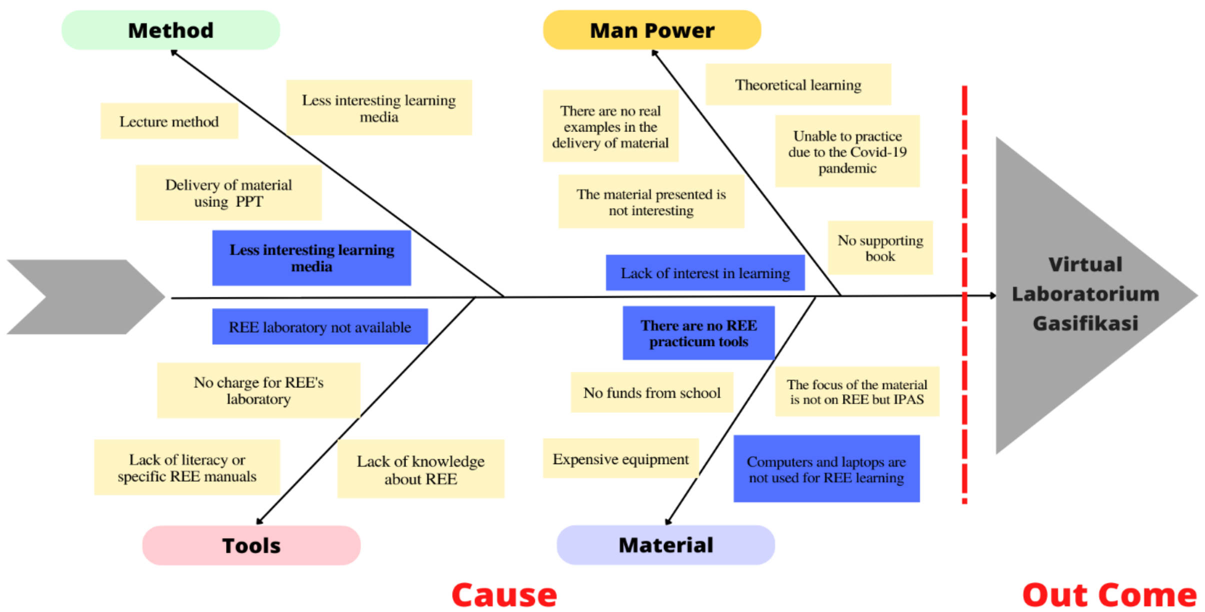


Fig. 1. Need analysis for primary development of Gasification Virtual Laboratory (GVL).

The results showed that VHS had problems with the tool for the gasification practicum. Several VHSs do not yet have a Renewable Energy Education (REE) Laboratory. VHS's investment in procuring equipment at the REE Laboratory is still lacking. This condition causes a lack of knowledge and literacy among VHS students in REE. The impact of the budget unavailability for the provision of the REE laboratory has resulted in no budget allocation for purchasing practicum materials. Many VHSs do not invest in purchasing practicum materials, especially for gasification practicum materials. Investments in practicum materials in schools tend to be used to purchase natural and social sciences (IPAS) learning practicum materials. On the other hand, several VHSs have the potential for computer laboratories and internet networks that have not been used optimally to support REE learning. If the teachers at VHS can take advantage of the potential of the computer laboratory in REE learning, then the achievement of student competencies will be better.

The initial analysis results related to REE learning at VHS also found few human resources, especially teachers with primary education in renewable energy. Respondents The teachers in this study said there were not many supporting books for REE learning. Thus, references for teaching REE to VHS students are also limited. Problems that arise in laboratory equipment, Manpower, and reference books related to REE, cause the learning methods delivered by teachers to tend to be monotonous and uninteresting. The conclusion drawn from the needs analysis is that learning at VHS requires: 1) a laboratory for REE practicum, 2) a reference for teaching REE, and 3) learning media that can make REE learning more enjoyable for students.

In this study, an analysis of student learning outcomes was carried out in REE learning. Scores of student learning outcomes analyzed were 71 students. Fig. 2 presents a detailed score of student learning outcomes in REE at VHS. The passing grade for learning at VHS is 70. These results show that two students achieve a passing grade in the "good" category and 16 students in the "passing" category. At the same time, 53 (74.6%) students have not fulfilled the passing grade. Suppose seen from the percentage of students who have not passed shows that it is necessary to improve REE learning in VHS. Observations of students who had not passed stated that the lack of understanding of REE, especially the gasification sub-competence, was caused by 1) limited gasification practicum equipment, 2) the material being taught was not specific and still general, and 3) reference sources in the form of books were still limited. So the solution to this problem is the development of a Virtual Laboratory to support REE learning. The Virtual Laboratory developed in this phase is to support gasification learning in VHS.

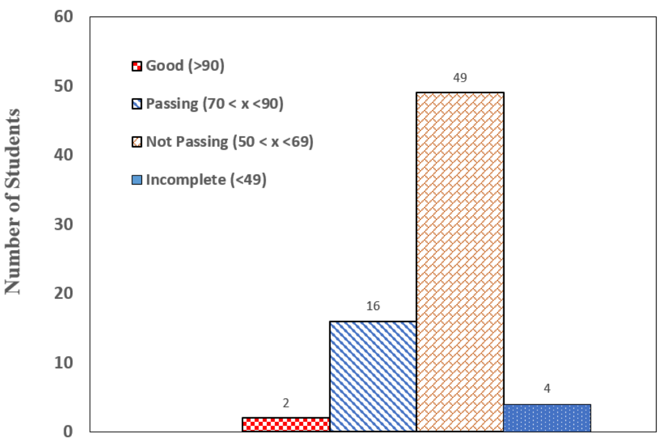


Fig. 2. Student REE scores.

Gasification is a thermochemical energy conversion process that utilizes biomass or coal converted into Syngas. The main composition of Syngas is H_2, CO, and CH_4. Therefore, gasification is appropriate for converting biomass to produce synthetic gas. In addition, gasification produces gas that can be used for power generation and small-scale gas generation for burning motorized vehicles. The supply of renewable biomass energy in Indonesia in 2018 was 68 million barrels of oil equivalent (BOE), the highest compared to 0 million BOE for water, 0 million BOE for wind, and 26 million BOE for geothermal [6]. Energy needs in Indonesia can be seen in Fig. 3. Based on energy needs in Indonesia, the top three energy uses are coal, oil, and biomass. The use of 13% biomass shows that renewable energy in Indonesia has a role and good prospects.

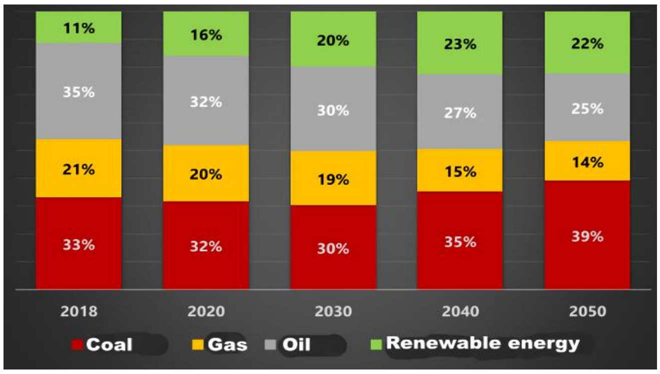


Fig. 3. Energy demand in Indonesia [6].

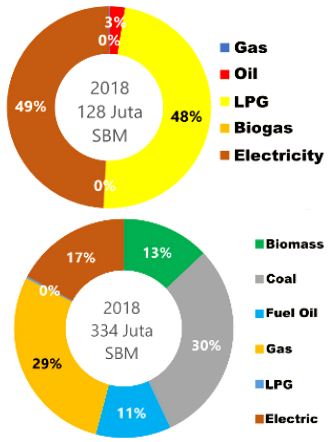


Fig. 4. Consumption in the household sector and the industrial sector [6].

Based on the positive trend of using renewable energy in Indonesia, an understanding of REE needs to be instilled in the younger generation. However, the learning outcomes related to REE in VHS are still far from ideal conditions. Using a GVL is expected to generate students' understanding and interest in learning. The development of GVL must be based on suitability with the content and achievement of student competencies so that GVL can be used optimally in learning. GVL is an interactive medium to overcome limitations in REE learning at VHS. Through GVL, these limitations, REE learning, as in the results of the needs analysis above, can be completed. GVL was developed to convey information and knowledge to students by combining text, audio, video, and graphics.

GVL is a breakthrough in learning media development by utilizing information and communication technology. GVL was made due to limited tools and materials in conventional laboratories. The low interest of VHS students in learning REE is the driving force for the need to develop instructional media that can make learning easier. GVL is expected to increase students' interest in learning because it contains fun and interactive REE material content. According to Mimi [30] states that learning by using audio-visual can motivate and enhance learning. GVL also has exciting features that can increase students' desire to learn. GVL is suitable for use during the Covid-19 pandemic. According to Yeni [31], VL is used because of limited learning time. Therefore, it is ideal for use during the Covid-19 pandemic.

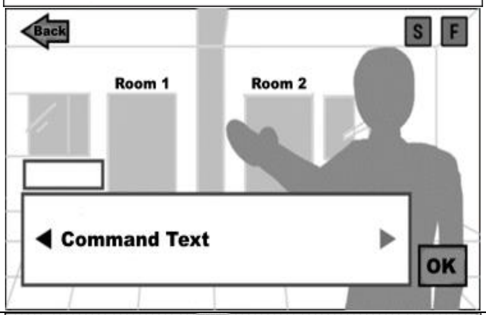
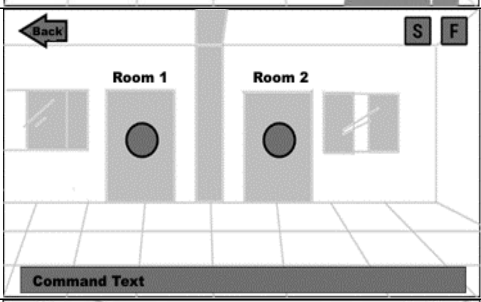
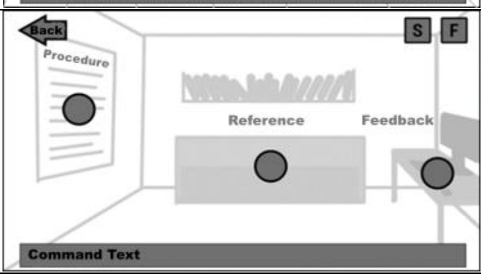
B. Design of Gasification Virtual Laboratory (GVL)

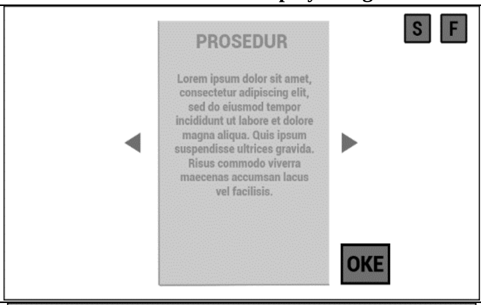
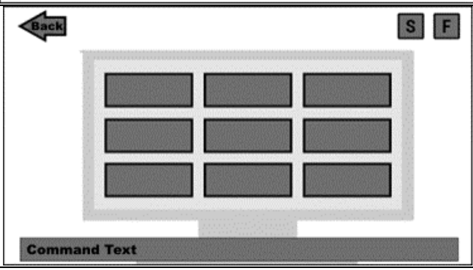
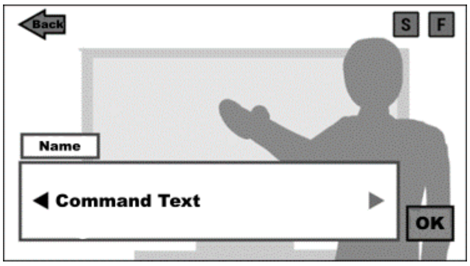
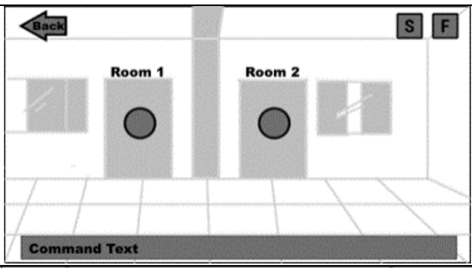
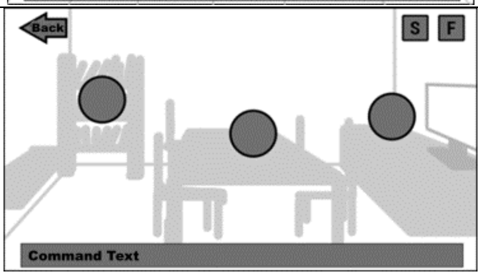
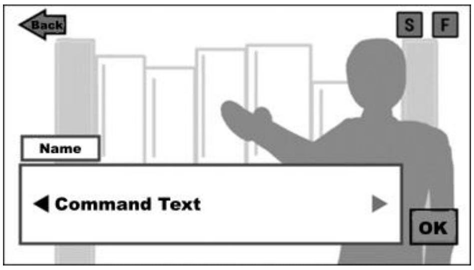
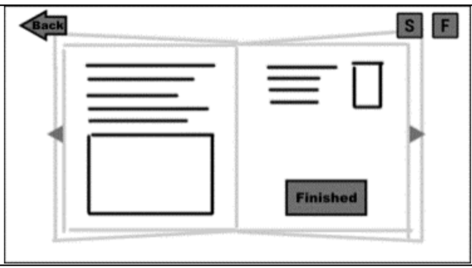
The development of information and communication technology impacts teaching methods in schools. This learning method answers the challenges and limitations of learning facilities and school infrastructure. In addition, using technology in schools is also a learning adaptation to adjust to changes in the current generation of students close to digitalization. The presence of a virtual laboratory is one of the means to accommodate the learning needs mentioned above [21]. According to D. Ibrahim [22], virtual laboratories are more affordable and can increase interaction between teachers and students. Therefore, a virtual laboratory is considered a solution to learning problems and efforts to achieve student competency.

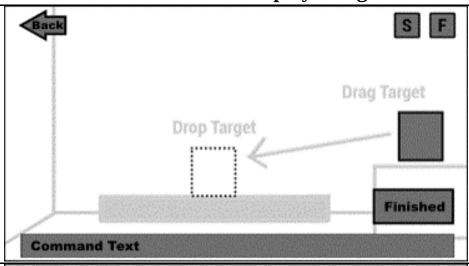
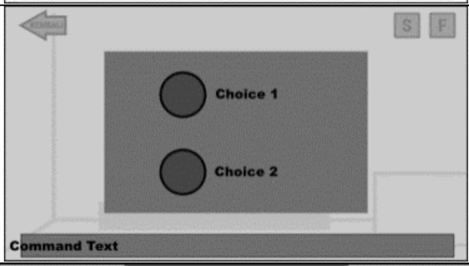
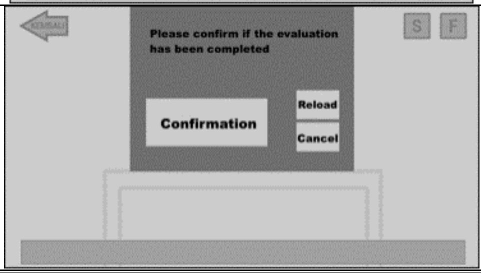
Researchers have conducted a needs analysis related to REE. Based on the needs analysis data, a GVL was developed, suitable for VHS students. In developing the GVL, the software consists of Adobe Animate, Corel Draw, Adobe Photoshop, Blender, and Format Factory. Adobe Animate is used to design a virtual gasification tool for biomass materials. Creating and editing 2-dimensional objects in this study uses Corel Draw software. Creating and editing photos of the gasification process at GVL is done using Adobe Photoshop software. Blender software is used to create and edit images related to the environment and atmosphere in the laboratory. Lastly, the Format factory is used to convert audio and video.

The initial stage of GVL development starts with making a storyboard and designing the experimental gasification process. The GVL development environment is based on the existing gasification equipment in the Energy Conversion & Combustion Laboratory. After the storyboard is formed, the second stage is to discuss and evaluate the storyboard with media experts and REE learning experts. The results of the evaluation and discussion are then used to revise the storyboard. Table II presents the results of the storyboard design stage after revision.

TABLE II: THE STORYBOARD OF GASIFICATION VIRTUAL LABORATORY

No	Display Design	Information
1		1. Basic UI - Button sound on / off (S) - Button full screen (F) 2. Navigation - Start Button (go to the introduction of the lobby) - Exit button (open exit prompt) 3. Illustration picture - UNS Logo - ECCL Logo
2		4. Basic UI - Sound button (S) - Full-screen button (F) 5. Navigation - Back button (go to the main menu) 6. Textbox - Guide name - Explanation text - Next button (go to the subsequent explanation) - Prev. button (go to the previous explanation) - OK button (go to the lobby) - Guide character (2D)
3		1. Basic UI - Sound button (S) - Full-screen Button (F) 2. Navigation - Room 1 entry button - Room 2 entry button - Back button (go to the main menu) Command Text
4		1. Basic UI - Sound button (S) - Full-screen button (F) 2. Navigation - Procedure button (go to R1 procedure) - Reference button (Go to R1 reference) - Feedback button (G to R1 feedback) - Back button (go to the lobby) Command Text

No	Display Design	Information
5		1. Basic UI - Sound button (S) - Full-screen button (F) 2. Navigation - Next button (go to the next page) - Prev. button (go to the previous page) - OK button (go back to room 1) Text/procedure image (2D)
6		1. Basic UI - Sound button (S) - Full-screen button (F) 2. Navigation - Back button (go to room 1) 3. Reference link button on the monitor Command Text
7		1. Basic UI - Sound Button (S) - Full-screen button (F) 2. Navigation - Back Button (Go To room 1) 3. Textbox - Guide Name - Monolog Text / Explanation - Next Button (Go to the subsequent explanation) - Prev Button (Go to the previous explanation) - OK Button (Go to R1 Feedback) - Guide Character (2D)
8		1. Basic UI - Sound Button (S) - Full-screen button (F) 2. Navigation - Room 1 Entry Button (Go to the introduction of room 1) - Room 12 Entry Button (Go to the introduction room 2) - Back Button (Go to Main Menu) Command Text
9		1. Basic UI - Sound Button (S) - Full-screen Button (F) 2. Navigation - Theory Button - Simulator Button - Evaluation Button - Back Button (Go to the lobby) Command Text
10		1. Basic UI - Sound Button (S) - Full-screen Button (F) 2. Navigation - Back Button (Go to Room 2) 3. Textbox - Guide Name - Explanation Text - Next Button (Go to the subsequent explanation) - Prev Button (Go to the previous explanation) - OK Button (Go To R2 Theory)
11		1. Basic UI - Sound Button (S) - Full-screen Button (F) 2. Navigation - Back Button (Go to R2 Theory) 3. Material - Text / Picture - Next Button (Go to the next page) - Prev Button (Go to the previous page) - Finish Button (closing material)

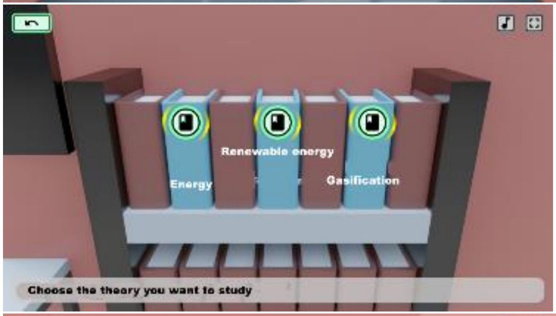
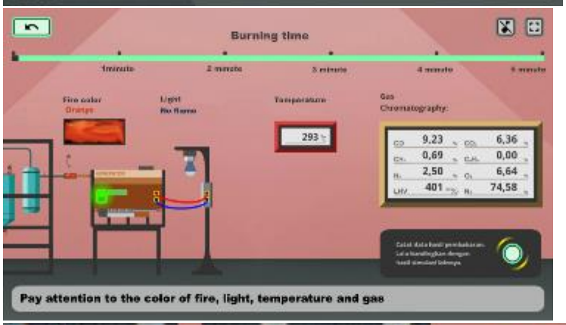
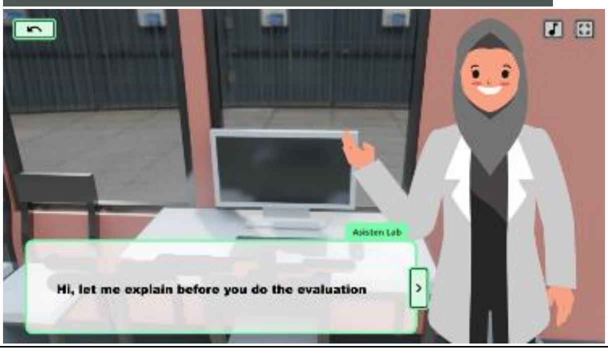
No	Display Design	Information
12		1. Basic UI - Sound Button (S) - Full-screen Button (F) 2. Navigation - Finish Button (Go to R2 Simulation) - Back Button (Go to R2 Simulator) 3. Assembly Area - Drag part - Drop part Command Text
13		1. Navigation - Option Key 1 (Go to simulation 1) - Option Key 2 (Go to simulation 2) Command Text
14		1. Navigation - Explanation Text - Confirmation Button (Go to room 2) - Reload Button - Cancel Button (Go to R2Evaluation)

GVL is prepared based on storyboards that have received improvements and corrections from learning media and REE learning experts. Details of the GVL development results can be seen in Table III. Students will get a landing page view the first time they open GVL, as shown in Fig. 5. Students can start using GVL by clicking the "Start" button. When the "Start" button is clicked, students will enter the front room of the laboratory. The front page of GVL has two rooms (rooms 1 and 2), as shown in Fig. 6. Regulations that apply when using GVL. First, students must participate in all activities in room 1 and can only enter room 2. Second, after room 2 is open, students must participate in activities until they finish.

Room 1 has three activities that must be completed by students (Fig. 7). The first activity, students must learn practicum procedures, equipment in the gasification process, and work safety tools at GVL. In the second activity, students learn about gasification from various reference sources available at GVL. Finally, in the third activity, students must provide feedback on implementing the first and second activities. Feedback from students is then used to improve the learning process at GVL.

TABLE III: DESIGN OF VIRTUAL LABORATORIES

No	Design	Information
1		Fig. 5. Initial view of the virtual gasification laboratory
2		Fig. 6. Laboratory virtual space view

No	Design	Information
3		Fig. 7. Room 1 display includes: procedures, references, and feedback
4		Fig. 8. Room 2 display includes: reading material, practicum, and evaluation
5		Fig. 9. Books reference
6		Fig. 10. Practical room, gasification machine installation
7		Fig. 11. Practicum room, simulating the application of gasification machines
8		Fig. 12. Evaluation room

After students finish their activities in room 1, they will receive instructions to move to room 2. In-room 2, students will carry out the core activities in GVL, which include reading books, doing practicum and simulations, and working on evaluation questions (Fig. 8). Students are required to carry out activities in room 2 sequentially. Before carrying out practicums and simulations, students are required to read books. GVL provides reference books related to practicum and simulation activities such as energy, renewable energy sources, waste to energy, and gasification (Fig. 9). The practicum button in room 2 will open if students have finished reading the practicum preparation reference books. Fig. 10 shows a space for students to carry out gasification experiments. The activities carried out by students during the practicum were 1) students analyzed the function of tools and materials in the gasification process, 2) students assembled gasification machines, and 3) students conducted gasification experiments. Fig. 11 shows students conducting an experiment and analyzing the effect of the type of RDF and the length of time it burns on a gasification engine. Finally, students conduct evaluations to measure the knowledge and skills acquired after completing the experiment at GVL (Fig. 12).

C. The Results of Testing the Display and Visual Aspects

Previously, GVL had been validated by REE learning content experts and REE learning media experts, so the next phase was testing the display and visual aspects. The display test aims to assess whether the GVL already has a display following the gasification practicum sequence. The display aspect is measured using eight indicators.

Q1 Media development is carried out efficiently and effectively

Q2 Attractive-oriented virtual laboratory interface0

Q3 The developed media can be used effectively and efficiently

Q4 Media can be managed or maintained easily

Q5 Learning media can be operated easily

Q6 Instructions for use are presented clearly

Q7 App used right

Q8 The media developed is free of advertisements, with instructions for use.

Visual testing was conducted to determine whether the GVL visual appearance provided practical experience following a natural gasification laboratory. Again, seven indicators are used to measure the suitability of the visual aspects of the GVL.

Q9 The choice of letters used is appropriate

Q10 Selection of appropriate color degradation

Q11 The layout of the design pattern used is appropriate

Q12 The image display used is by the material

Q13 The selection of sound effects used is appropriate

Q14 The media design is presentable

Q15 Display layout design with the appropriate character of vocational high school students

Respondents on the measurement of display and visual aspects comprised 15 teachers, 71 students, and three learning media experts. Fig. 13 shows the results of testing the display aspect of the GVL. The average display aspect test results show 92.8%. These results indicate that the display on the GVL has complied with the sequences in the gasification study. However, in the Q3 indicator: The developed media can be used effectively and efficiently, but the results could be more optimal. So it is necessary to revise the effectiveness and efficiency of GVL development. Likewise, in the Q5 indicator: Learning media can be operated easily, and the respondent wants GVL to be even more accessible.

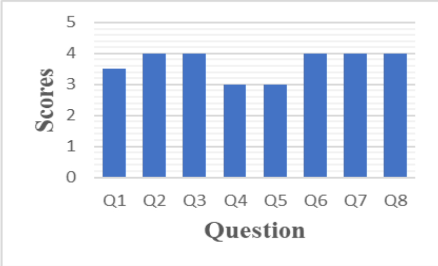


Fig. 13. Device display aspect results.

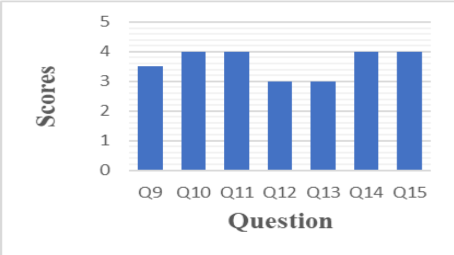


Fig. 14. Device visual aspect results.

The results of the visual aspect test (Fig. 14) also showed a positive response from the respondents. Respondents stated that GVL could visually present a gasification laboratory with an average test result of 85.75%. The visual aspect test's average results still need to be higher than the display aspect test. Indicators Q12 and Q13 on the visual aspect must be improved. Indicator Q12: The image display used is by the material. According to the respondent, there is a need to improve the image of the GVL. In Indicator Q13, respondents assessed that the sound effects on GVL needed to be adjusted to the gasification practicum activity. Based on the test results of the display aspect and the visual aspect, the GVL is improved so that it can support user comfort. The results of the GVL repair can be seen in Table IV.

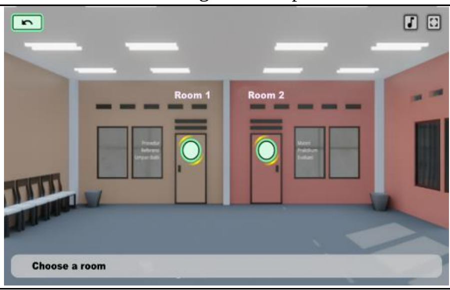
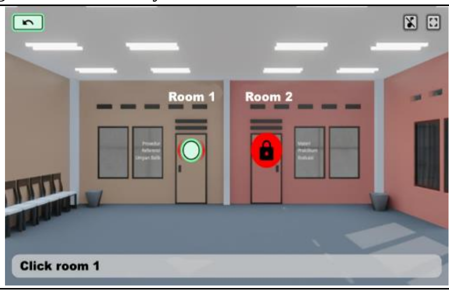
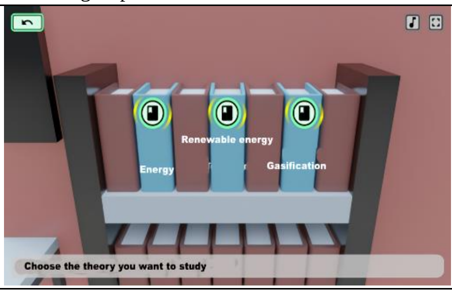
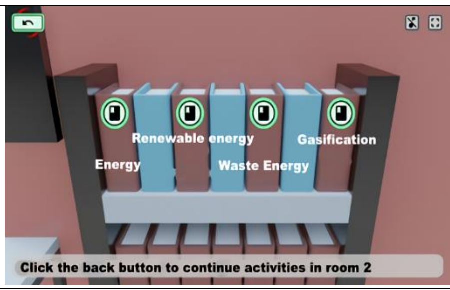
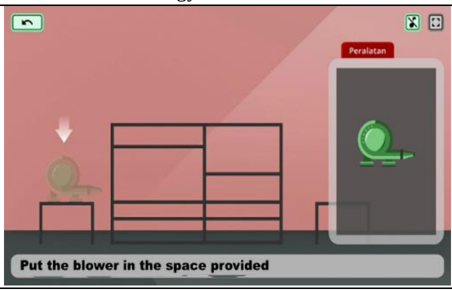
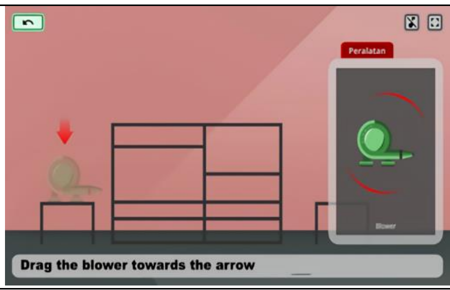
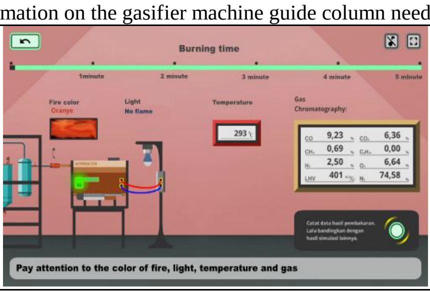
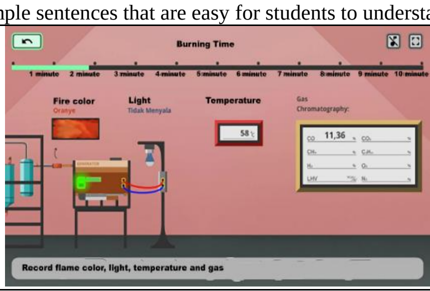
The development of GVL has gone through a series of forum group discussion processes and testing, so GVL is feasible to be implemented as a VHS learning medium. GVL also has a role in REE learning that is effective, efficient, and easy to use. Attractive designs and illustrations make students more interested and enthusiastic about participating in the REE learning process at VHS. The positive impact of using GVL is that students do not get bored quickly when studying. In addition, GVL can support distance learning. Martin and Chebak [26] stated that virtual laboratories could facilitate students in connecting theoretical and practical aspects. Ángel [32], in his research related to natural and virtual bioreactor laboratories, stated that virtual laboratories could

1. Make students more motivated to participate in laboratory sessions;
2. Make students think this practice is helpful, and teachers can assess student performance

significantly in the laboratory;
3. Make students have better discussions in class;
4. Integrating natural experiments with virtual computer simulations enhances the learning process;

GVL results of this research can be accessed and available at the following link: https://gasification.rumahvokasi.com/.

TABLE IV: RESULTS OF EXPERT VALIDATION OF RENEWABLE ENERGY MEDIA AND MATERIALS

No	Before revision	After revision
1		
	The revision results of the learning media experts: The arrow navigation color is changed to red to clarify the instructions.	
2		
	The revision results of the learning media experts: Room 2 in the virtual gasification laboratory needs to be locked so that students can be coherent in carrying out learning steps.	
3		
	The revision results of learning media experts: The material in the virtual gasification laboratory needs to add waste energy material so that students know how to use waste as energy.	
4		
	The revision results of learning media experts: 1. The arrow navigation color must be replaced with a bold one to make it visible. 2. The information on the gasifier machine guide column needs to be changed using simple sentences that are easy for students to understand.	
5		
	The revision results of the learning media experts: The 10-minute burning time is made into one window to make the display more practical.	

IV. CONCLUSION

The resulting study presented a virtual laboratory development design used as a learning media for VHS students. GVL was prepared based on the needs of VHS students and to overcome the problem of high investment in renewable energy laboratories. The learning process at VHS requires applying learning media that is interesting, not boring, and can lead students to achieve learning competencies. GVL development for VHS students has been made and tested for feasibility. Based on the assessment results, the average validation of learning media and material experts was 92.18% agreeing with the display aspect. As for the visual aspect of, 85.75%. Based on these values, GVL is feasible for learning renewable energy. In practice, GVL is expected to overcome difficulties in delivering REE materials.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Gesti Khoirunnisa conducted the data search, constructed the concepts, and wrote the initial draft.

Herman Saputro reviewed the concept and refined the manuscript draft.

AG Tamrin reviewed the initial manuscript.

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REFERENCES

[1] E. Outlook, "Energy Outlook 2020 edition explores the forces shaping the global energy transition out to 2050 and the surrounding that," *Energy Outlook 2020 Ed. Explore. Forces Shap. Glob. Energy Transit. Out to 2050 Surround.*, p. 81, 2020.

[2] BPPT, *Indonesia Energy Outlook 2020 - Special Edition Dampak Pandemi COVID-19 terhadap Sektor Energi di Indonesia Diterbitkan*, 2020.

[3] J. O. Jaber *et al.*, "Renewable energy education in faculties of engineering in Jordan: Relationship between demographics and level of knowledge of senior students'," *Renew. Sustain. Energy Rev.*, vol. 73, no. February 2016, pp. 452–459, 2017, DOI: 10.1016/j.rser.2017.01.141.

[4] O. Ocal and A. Aslan, "Renewable energy consumption-economic growth nexus in Turkey," *Renew. Sustain. Energy Rev.*, vol. 28, pp. 494–499, 2013, DOI: 10.1016/j.rser.2013.08.036.

[5] H. Saputro, T. Firdani, R. Muslim, Y. Estriyanto, D. S. Wijayanto, S. Lasmini, and Khaniffudin, "The CFD simulation of cyclone separators without and with the counter-cone in the gasification process the CFD simulation of cyclone separators without and with the counter-cone in the gasification process," 2018, DOI: 10.1088/1757-899X/288/1/012142.

[6] BPPT, *Indonesia Energy Outlook 2020 - Special Edition Dampak Pandemi COVID-19 terhadap Sektor Energi di Indonesia*, no. August. 2020.

[7] H. Lucas, S. Pinnington, and L. F. Cabeza, "Education and training gaps in the renewable energy sector," *Sol. Energy*, vol. 173, no. July, pp. 449–455, 2018, DOI: 10.1016/j.solener.2018.07.061.

[8] P. Jennings, "New directions in renewable energy education," *Renew. Energy*, vol. 34, no. 2, pp. 435–439, 2009, doi: 10.1016/j.renene.2008.05.005.

[9] E. Kacan, "Renewable energy awareness in vocational and technical education," *Renew. Energy*, vol. 76, pp. 126–134, 2015, doi: 10.1016/j.renene.2014.11.013.

[10] J. López-De-Armentia, D. Casado-Mansilla, S. López-Pérez, and D. López-De-Ipiña, "Reducing energy waste through eco-aware everyday things," *Mob. Inf. Syst.*, vol. 10, no. 1, pp. 79–103, 2014, doi: 10.3233/MIS-130172.

[11] D. Gervais, "Reducing energy waste via occupant behavior: The role of the individual in climate change solutions," no. May, p. 55, 2019.

[12] J. Du and W. Pan, "Examining energy-saving behaviors in student dormitories using an expanded theory of planned behavior," *Habitat Int.*, vol. 107, no. September 2020, p. 102308, 2021, DOI: 10.1016/j.habitatint.2020.102308.

[13] K. Sun and T. Hong, "A framework for quantifying the impact of occupant behavior on energy savings of energy conservation measures," *Energy Build.*, vol. 146, pp. 383–396, 2017, DOI: 10.1016/j.enbuild.2017.04.065.

[14] C. Acikgoz, "Renewable energy education in Turkey," *Renew. Energy*, vol. 36, no. 2, pp. 608–611, 2011, doi: 10.1016/j.renene.2010.08.015.

[15] S. Buldur, M. Bursal, N. Yalcin Erik, and E. Yucel, "The impact of an outdoor education project on middle school students' perceptions and awareness of the renewable energy," *Renew. Sustain. Energy Rev.*, vol. 134, no. December 2019, p. 110364, 2020, DOI: 10.1016/j.rser.2020.110364.

[16] B. Sucic, P. Lah, and B. P. Visocnik, "An education and training program for energy managers in Slovenia – Current status, lessons learned and future challenges," *J. Clean. Prod.*, vol. 142, pp. 3360–3369, 2017, DOI: 10.1016/j.jclepro.2016.10.133.

[17] R. Muslim, H. Saputro, and A. Thamrin, "Case study: Vocational student's knowledge and awareness level toward renewable energy in Indonesia," *Open Eng.*, vol. 11, no. 1, pp. 690–708, 2021, DOI: 10.1515/eng-2021-0067.

[18] and R. K. E Wiwin, SR Hakim, "The use of physics tricks to practice critical thinking skills in senior high school," 2020, DOI: 10.1088/1742-6596/1491/1/012064.

[19] D. Pratiwi, S. Astutik, and M. Maryani, "Model Pembelajaran Collaborative Creativity (CC) berbantuan virtual laboratory pada Pembelajaran Fisika di SMA," *J. Pembelajaran Fis.*, pp. 229–234, 2018.

[20] Y. M. Cholily and A. Inam, "Peluang Pemuatan Energi Matahari ke Kurikulum Sekolah Menengah Pertama," pp. 819–822, 2017.

[21] M. M. Ratamun and K. Osman, "The effectiveness of virtual lab compared physical lab in the mastery of science process skills," *Probl. Educ. 21st Century*, vol. 76, no. 4, pp. 544–560, 2018.

[22] D. Ibrahim, "Procedia computer engineering simulation with MATLAB : Improving teaching and learning effectiveness," *Procedia Comput. Sci.*, vol. 3, pp. 853–858, 2011, doi: 10.1016/j.procs.2010.12.140.

[23] R. Pastor *et al.*, "Renewable energy remote online laboratories in Jordan universities: Tools for training students in Jordan," *Renew. Energy*, vol. 149, pp. 749–759, 2020, doi: 10.1016/j.renene.2019.12.100.

[24] M. M. Ratamun and K. Osman, "The effectiveness comparison of virtual laboratory and physical laboratory in nurturing students' attitude towards chemistry," *Creat. Educ.*, vol. 09, no. 09, pp. 1411–1425, 2018, DOI: 10.4236/ce.2018.99105.

[25] R. Millar, "The role of practical work in the teaching and learning of science," no. October 2004.

[26] S. S. Martin and A. Chebak, "Concept of educational renewable energy laboratory integrating wind, solar and biodiesel energies," *Int. J. Hydrogen Energy*, vol. 41, no. 45, pp. 21036–21046, 2016, doi: 10.1016/j.ijhydene.2016.06.102.

[27] I. Calvo, M. Marcos, D. Orive, and I. Sarachaga, "Building complex remote learning laboratories," *Comput. Appl. Eng. Educ.*, vol. 18, no. 1, pp. 53–66, 2010, DOI: 10.1002/cae.20239.

[28] M. Bima, H. Saputro, and A. Efendy, "Virtual laboratory to support a practical learning of micro power generation in Indonesian Vocational high schools," *Open Eng.*, vol. 11, no. 1, pp. 508–518, 2021, DOI: 10.1515/eng-2021-0048.

[29] Thiagarajan, "Instructional development for training teachers of exceptional children: A sourcebook," *J. Sch. Psychol.*, vol. 14, no. 1, p. 75, 1976, DOI: 10.1016/0022-4405(76)90066-2.

[30] K. Mimi, "The use of audio visual to improve listening," *English Educ. J.*, vol. 7, no. 2, pp. 233–245, 2016.

[31] L. F. Yeni, "Pengembangan virtual laboratory berbasis multimedia interaktif pada mata kuliah microbiology sub materi isolasi bakteri," *J. Pendidik. Mat. dan IPA*, vol. 6, no. 1, pp. 57–67, 2016, doi: 10.26418/jpmipa.v6i1.17591.

[32] S. A. Ángel, "Real and virtual bioreactor laboratory sessions by STSE-CLIL WebQuest," *Educ. Chem. Eng.*, vol. 13, pp. 1–8, 2015, DOI: 10.1016/j.ece.2015.06.004.

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