Virtual Laboratory for Online Practicum Learning

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Abstract: The social distancing policy as the basis for implementing learning from home makes it difficult for some teachers and students to adapt due to sudden changes. Online practicum learning at SMK is more challenging to implement. Students must possess the demands cognitive, affective, and psychomotor competencies. The main challenge for online learning in vocational education is how to expand traditional practice laboratories to the internet. This article synthesizes the study of virtual laboratories for online practicum learning. Articles published in the last five years are systemically reviewed. The existence of a laboratory that is fundamental to the experimentation of an object needs to be confirmed for its existence. Initially, virtual laboratories were developed to manipulate the presentation of difficult-to-handle materials in natural laboratories and abstract overview concepts. Opportunities to manage content that resembles actual conditions, visualization of complex materials, limited resources that can be overcome, personalization of learning, the minimal possibility of work accidents, the flexibility of time are the advantages of a virtual laboratory. Students are assumed to experience real-life education in the laboratory. Pre-practicum demonstrations in natural laboratories provide an opportunity to increase the achievement of learning objectives. Types of virtual laboratories that can be developed in online practicum learning are video-based laboratories, web-based laboratories, and remote-based laboratories. With the existence of a comprehensive study, the research results can be a reference for the development of virtual laboratory media for vocational learning.

Keywords: online learning, online practicum, pandemic, virtual laboratory.

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1. Introduction

One of the Covid-19 pandemic impacts is the emergence of social distancing policies (Thunström et al., 2020). This policy exists to minimize the rate of spread in society (Michie et al., 2020). Social distancing is the basis for implementing learning from home by utilizing information and communication technology. It is not uncommon for teachers and students to have difficulty adapting to changes that occur suddenly. The use of information and communication technology has been implemented in recent years in the education system in Indonesia, but it has not been evenly distributed (Churiyah et al., 2020). In vocational education, online learning is more challenging to implement than general education (Violante & Vezzetti, 2014). Practical knowledge in vocational education requires students to have cognitive, affective, and psychomotor competencies (Rosina et al., 2021; Handayani et al., 2020; Sangsawang, 2020; Ana, 2020; Al-Najar & Hamarneh, 2019; Maryanti & Nandiyanto, 2023).

The balance between cognitive, affective, and psychomotor aspects is not obtained instantly. It takes learning activities that can train to understand knowledge and skills. An understanding of knowledge rests on the ability to understand what is known. By understanding a concept, the concept's meaning can be applied to a variety of different conditions. If students can correctly answer all questions related to the same idea, then these students have a good understanding of knowledge. Practicum with an online learning system is more challenging to implement (Bahasoan et al., 2020). A laboratory in practicum learning is assumed to significantly affect student learning outcomes, especially in the psychomotor aspects (Feisel & Rosa, 2005). In online learning during the current pandemic, several practicum alternatives can be presented, such as implementing practicum from home with limited availability of practical facilities, or practicum implementation is still carried out directly by implementing health protocols and limiting time and amount. Practitioners. This condition supports the emergence of online practicum learning media innovation.

It is hoped that the design and development of online practicum facilities can support practicum implementation during a pandemic. One of the online learning facilities and infrastructure that can help implement the practicum is a virtual laboratory (Waldrop, 2013). A virtual laboratory is a form of laboratory-developed software and is run by the system (Fabregas et al., 2017). All tools and materials needed by the laboratory can be found in the software. Content developed in a virtual laboratory can be engineered to resemble natural conditions. Practical implementation using virtual laboratories can be more focused because students systematically follow the guidelines in the developed media and at a predetermined time (Potkonjak et al., 2016). In addition, the availability of work steps helps teachers explain the stages of the practicum without having to explain them first. Simulations in virtual laboratories can create a learning process that is much more efficient and can be applied to problems or situations such as the real world to improve students' conceptual mastery abilities (Martínez et al., 2011). Students are expected to get a practical learning experience like in a natural laboratory or similar.

Virtual laboratories were initially developed to manipulate the presentation of complex materials in natural laboratories and abstract overview concepts (Ramírez et al., 2020). Simulation-based learning is emerging as a new tool that can replace and enhance interactive learning experiences. Learning techniques using simulations play a crucial role in classroom settings to provide students with the required knowledge and skills (Seifan et al., 2020). One essential feature of the virtual laboratory is that it allows students to learn from failure without causing actual harm.

Many new technologies have been used to develop virtual laboratories (Gunawan et al., 2017). The types of virtual laboratories being designed to include augmented reality-based (Herlandy et al., 2019), website-based virtual laboratories (Handayani et al., 2018), virtual laboratories based on mobile virtual reality (Triatmaja & Khairudin, 2018), 3d virtual simulation (Damasceno et al., 2017), and a remote laboratory-based virtual laboratory (Bisták et al., 2017). In general, the factors that must be considered in developing a virtual laboratory include software engineering, visual communication, material relevance, ease of use, and the language used in the system (Handayani et al., 2018). This study analyzes virtual laboratories that can be developed in vocational education by considering the ease of use to support online practicum learning. With comprehensive research, research results can be used as a reference for developing virtual laboratory media for vocational education.

2. Theoretical framework

The main challenge of online learning in engineering is how to expand traditional practice laboratories to the internet. There are two approaches to developing online laboratories, virtual laboratories, and remote laboratories. A virtual laboratory can be defined as multi-sensory software with interactivity to simulate certain practicums by replicating conventional laboratories (Gunawan et al., 2017). The virtual laboratory allows students to learn through a case study approach, interact with laboratory equipment, conduct experiments, analyze experiments while evaluating the processes being carried out. Students can see inside the devices they operate through visual displays, animations, and adaptable representations of natural laboratories (Koretsky et al., 2008). With virtual labs, the possibilities for exploring, experimenting, and learning are even more dynamic laboratories.

In its use, a virtual laboratory requires hardware that supports specific input from its users, such as pressing buttons, pressing the screen, or through the movement of the user's body. The types of hardware for operating virtual laboratories are increasingly diverse as technology develops. Devices for running a virtual laboratory can create a "low immersion" or "high immersion" experience. Laboratory simulations run on computers generally result in less immersive interactive learning environments. Whereas the use of virtual reality devices will result in high immersion, which is an immersive experience that places the user in a virtual environment that surrounds the user so that the user feels inside and is part of the simulation, the virtual laboratory is based on software to simulate the laboratory environment (Gunawan et al., 2017).

A virtual laboratory is based on software such as virtual laboratory instrumentation engineering workbench, Matlab / Simulink, Java Applet, Flash, or other software to simulate a laboratory environment. Virtual laboratories can be used for experiments that usually require too expensive equipment, unsafe tools, and materials that are not available. The virtual lab also allows students to repeat the experiment multiple times, allowing them to see how parameters and settings are changed. In addition, work accidents can be minimized (Gunawan et al., 2017). Many researchers on the development of virtual laboratories have reported their research results with different types of distribution.

Figure 1 shows the PhET virtual laboratory. The PhET virtual laboratory is an example of a virtual laboratory that runs on a computer platform in a two-dimensional graphic display. Users can run practicum through the computer screen with input interactivity from the keyboard or mouse button. The immersion experience obtained is low because practicum activities are represented by pressing buttons, touching, or moving the mouse. A flat workspace limits the interaction between laboratory equipment and users, and the input given is relatively different from actual conditions. Keyboard, mouse, or finger touch becomes an extension of the hand to carry out practicum activities. It can be said that the user does not directly touch the laboratory equipment (Ranjan, 2020).

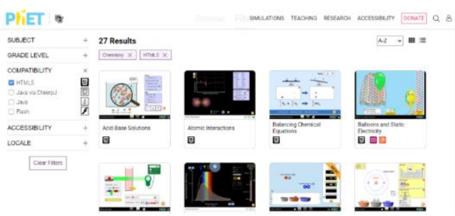

Fig.1 PhET virtual laboratory (www.phet.colorado.edu)

Figure 2 shows the virtual laboratory is an example of a virtual laboratory developed using a Head Mounted Display (HMD) device. Users can virtually enter the laboratory and access several types of practicum, complete with equipment and work procedures. The training is packaged with a case study approach, has a storyline that users can follow, and can evaluate the practicum results carried out (Ranjan, 2020). The use of virtual laboratories has various purposes, are:

1. Personalized learning

Figure 3 shows the Zona goldilocks virtual laboratory. Virtual laboratories provide technological tools to present a more personalized and specialized learning approach considering individual learning speed and needs. In conventional laboratories, the practicum process is generally carried out uniformly with the method determined by the teacher. This method tends to alienate low-achieving students. Virtual laboratories can support students with different learning styles by providing multi-sensory experiences. Students can understand practicum more freely, understand practicum methods more freely, do not need to worry about mistakes, and repeat training many times to conclude the correct practicum method by themselves. The virtual laboratory can be a tool for pre-practice before students carry out an actual practicum in a conventional laboratory (Ranjan, 2020).

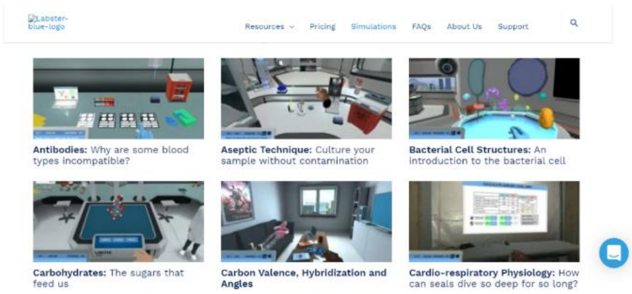

Fig. 2 Labster virtual laboratory (labster.com)

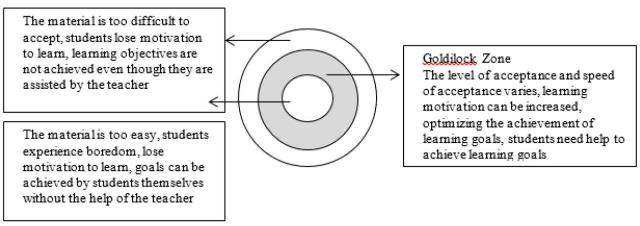

Fig. 3 Zona goldilocks virtual laboratory (Ranjan, 2020)

2. Overcoming limited resources

Virtual laboratories can provide a well-equipped laboratory with expensive equipment and low cost (Falode & Gambari, 2017). Students can have unrestricted access to laboratory settings such as equipment they usually would not use. The virtual laboratory can perform simulations precisely and be duplicated easily not to require high costs. Applications can be run during the trial waiting time; students can run the equipment in a virtual version, understand the technique, and operate it to understand it before running it for real more easily (Ranjan, 2020).

3. Complex visualization

Figure 4 shows the cardiovascular function simulation. Graphical visualization in a virtual laboratory allows abstract representations to be transformed into more concrete experiences that activate the students' minds in understanding certain concepts and enable experiential learning. Additionally, it can allow students to focus on critical concepts without distraction (Ranjan, 2020).

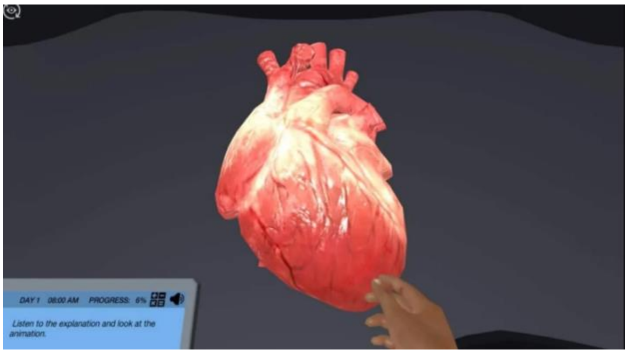

Fig. 4 Cardiovascular function simulation (www.labster.com)

4. Time flexibility

The time variable can be set in the virtual laboratory as accelerated, slowed down, stopped, or repeated. Students can repeat practicum in their spare time to help master complex concepts (Tobarra et al., 2020). For lab work that takes a long time, the simulation can be accelerated so that students can understand the stages that occur without having to wait for the actual time. Virtual laboratories can also be practical media so that students can find out about practicum procedures before going through simulations. Figure 5 shows the example of vacuum filtration simulation.

Fig. 5 Vacuum filtration simulation (evobooks virtual laboratory)

5. Minimizing Work Accidents

Figure 6 shows Virtual Chemlab calorimetry. Students can carry out practicum with various conditions that allow practical errors to occur. The simulation will analyze the requirements and errors made then provide feedback to the user. Applications can provide an assessment and will invite students to repeat the practicum. Students will know more about the steps taken in the next practicum (Ranjan, 2020).

3. Method

This research is a literature review. The research source comes from searching the literature. The literature review was identified by browsing the Web of Science database, followed by Scopus by entering the keywords "Virtual Laboratory" and "Online Practicum." As a result, as many as 40 articles in the last five years with 2016 and 2020. Of the 50 articles that were read, analyzed, and coded using a spreadsheet program. The coding scheme was adapted from a structured/systemic approach to a literature review. The approach uses four main categories in analyzing articles, namely 1) Basic data: author, year of publication, journal, place of research, 2) Research methods: research approaches, methods, themes, data collection, analysis methods, research results, 3) Content analysis, namely virtual laboratory analysis that can be developed for vocational education online practicum, 4) Discussion: issues discussed, future hints, personal comments.

Fig. 6 Virtual Chemlab calorimetry (www.chemlab.byu.edu)

4. Results and Discussion

The application of information and communication technology in education development is now mandatory. The result of digital technology has triggered a shift in the world of education from conventional (face-to-face) education to more modern or open education (Strimel & Grubbs, 2016). Online learning requires students to continue to develop skills, especially in vocational education; students are required to have abilities and skills. One solution that can be done is to create and design online learning facilities and infrastructure that can support the implementation of student practicum. Educators in this information age must have a sequential, sensory, and visual style of teaching. Educators should position students to be active learners, easy to learn by observing and drawing generalizations in the form of conclusions about what is being known (Saavedra & Opfer, 2012).

One of the facilities and infrastructure in online learning that can support the practicum implementation is a virtual laboratory (Waldrop, 2013). Learning using computer simulations can create a learning process that is much more efficient and can be applied to problems or situations such as the real world to improve students' mastery of concepts (Martínez et al., 2011). The development of digital technology combines with other critical technologies in changing the way you design, manufacture, commercialize and generate value from related products and services. Technological advances such as the Internet of Things (IoT), 5G, cloud computing, data analytics, and robotics are transforming products, processes, and business models across all sectors, ultimately creating new industry patterns as global value chains shift (Szalavetz, 2019).

One of the obstacles faced during the practicum can be overcome by using alternative learning media in a virtual lab. The virtual lab uses a computer program to simulate a series of experiments without performing any direct activity. Virtual labs can strengthen practicum activities that cannot be practiced in real terms, meaning that virtual lab work can be an alternative practicum media to replace the actual practicum if not possible. Virtual labs can support students to explore and visualize abstract concepts, especially in describing the application of science in a field (Başer & Durmuş,2010). The use of virtual labs in learning has several advantages, including (1) enabling students to produce other experimental work because it is time and cost-effective; (2) enabling students to obtain visualization at the macroscopic, submicroscopic, and symbolic levels; (3) gives a dynamic presentation of the world of submicron particles; (4) contributes to a better understanding of the chemical content; and (5) powerful motivational tools (Herga et al., 2014). Virtual labs can also improve conceptual and investigative performance (Chien et al., 2015). The virtual world can bring Science, Technology, Engineering, and Mathematics (STEM) to students through engaging and socially oriented activities (Zhou et al., 2019).

The use of virtual laboratories uses computers to simulate complex and expensive experimental devices or replace experiments in hazardous environments. The virtual laboratory allows students to visualize and interact with the phenomena experienced if they carry out experiments in a natural laboratory (Martínez et al., 2011). In addition, the virtual laboratory is a supporting factor to enrich the experience and motivate students to conduct experiments interactively and develop experimental skills activities. (Dobrzański & Honysz, 2011).

The development of a virtual laboratory can become a reference for the development of online practicum learning media in vocational education by considering the ease of user access, especially video-based laboratories, website-based laboratories, and remote-based laboratories.

4.1. Video-based laboratory

Video-based laboratories are practicum activities in the laboratory in the form of video-based educational software. Video-based laboratories can increase student motivation in finding a concept. This media can familiarize students with carrying out scientific activities digitally. Besides that, it also allows students to get closer to the various phenomena (Fadlilah et al., 2020).

The video-based activity provides students with a step-by-step overview of an actual laboratory, allowing them to visualize the entire experimental process and its environment through video. This model is the most widely used and most straightforward method of online learning. Below is an example of a video-based laboratory on pastry learning that shows in Figs. 7 and 8.

4.2. Web-based laboratory

Virtual activities that can be used to simulate real-world practice. According to one study, an artificial laboratory can be accessed via the internet, and where students look likely to enter the artificial lab. According to one study, virtual laboratory tools are just as effective as traditional laboratories at increasing students' knowledge and understanding because they promote inquiry-based active learning. The practicum simulation in a virtual laboratory provides the user an overview of how the food analysis steps correspond to the practicum in a natural laboratory. The simulation is interactive where the user can do the simulation directly on each step. The developed virtual laboratory is equipped with practical instructions, materials, and evaluation, making it a suitable alternative to online learning media, particularly for laboratory learning. An example of a web-based laboratory-developed on water content analysis material is shown in Figs. 9 and 10. They show the display of water-content analysis simulation.

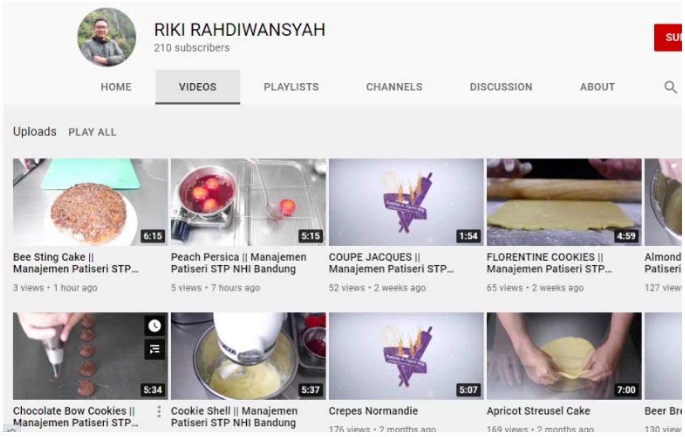

Fig. 7 Video-based laboratory on patisserie management material

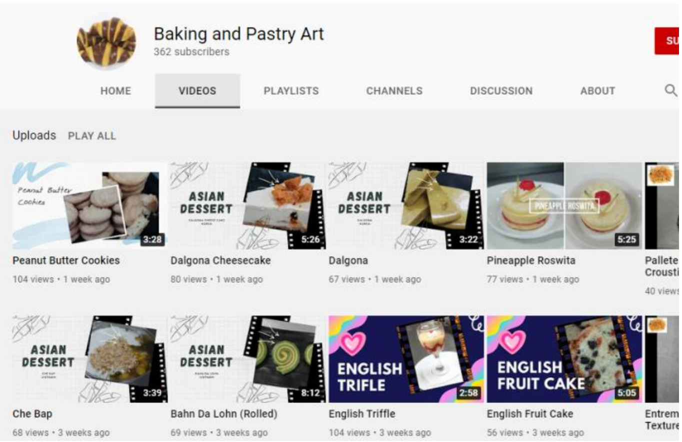

Fig. 8 Video-based laboratory on baking and pastry materials

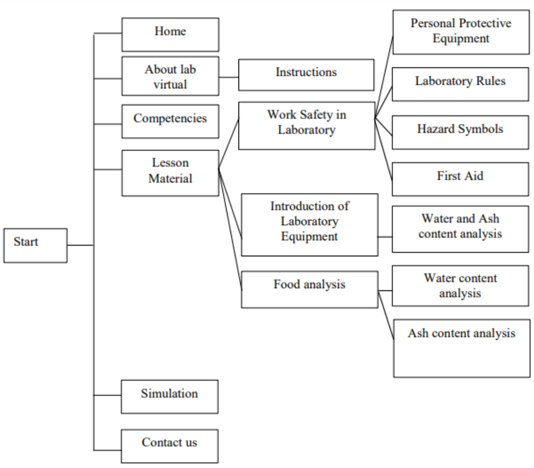

Fig. 9 Web-based laboratory flowchart (Khoerunnisa, and Sugiarti, 2018)

Fig. 10 The display of water content analysis simulation (labvirtual.agroindustri.upi.edu)

4.3. Remote-based laboratory

Through this technology, learners can access and use the laboratory equipment online remotely. As an example, research conducted by a lecturer from the electrical engineering program titled" A Remote Laboratory (RLab) for Distance Practical Work of Factory Automation "from 2017 up to now is beneficial during the pandemic as shown in Fig. 11. This system is helpful when conducting practicum with students. Laboratories are the most necessary facilities for engineering students to do valuable, practical work. Practical work in the industrial automation course is often inadequate to get much knowledge, so it is needed. Accessible remote-control software is adopted for realizing RLab, which would provide the natural experiment environment.

In addition, the limitations of this study need to be considered because this research was conducted when the COVID-19 outbreak occurred online or from home studies that need additional strategies for enhancing students' comprehension (Mulyanti et al., 2020; Hashim et al., 2020; Sangsawang, 2020; Hernawati & Nandiyanto, 2021; Nasution & Nandiyanto, 2021; Huwaidi et al., 2021; Maryanti, 2021; Ganesha et al., 2021; Ramdhani & Nandiyanto, 2021).

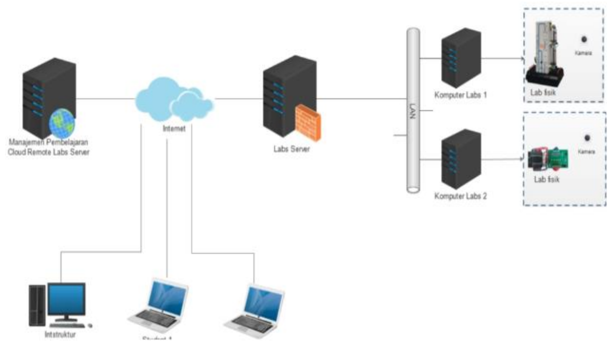

Fig. 11 RLab development (Nugraha & Haritman, 2020)

5. Conclusion

This article provides an overview of virtual laboratories as online practicum learning media developed in vocational education. Various types of virtual laboratories were presented. The advantages of using virtual laboratories during a pandemic have strengthened teachers to create practical learning tools and solve the assumption that achieving realistic learning objectives is more difficult to achieve through online learning. The advantages of using virtual laboratories are to manipulate content that resembles actual conditions, visualization of complex material, limited resources that can be overcome, personalization of learning, less possibility of work accidents, the flexibility of time, and practical work to be more fun with game features. With this virtual laboratory learning media, it is assumed that students will experience online learning similar to authentic learning in a laboratory. A virtual laboratory can be used for a demonstration before an actual practicum in the laboratory. This virtual laboratory can also meet student needs, such as giving freedom to students to do or carry out training anywhere and anytime without having to be guided by the teacher.

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