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Profiles of Facilities and Students' Responses in Supporting Implementation of Raspberry Pi-Based Bifocal Modeling Physics Practicum

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Abstract – *This research has been conducted to seek overviews of facilities and students' responses in supporting the implementation of Raspberry Pi-based bifocal modeling physics practicum. This research was a qualitative case study done in a senior high school in Bandung District, Indonesia. The subjects of this research were two physics teachers and seventy-nine of students enrolled in tenth, eleventh, and twelfth grades in the academic year of 2020/2021. The data collection in this research was carried out through observation, interviews, and questionnaire. Observation and interviews activities were focused on laboratory room, laboratory equipment, computer laboratory, and internet facilities to obtain adequate information due to facilities which is potential to support the implementation of Raspberry Pi-based bifocal modeling physics practicum based on the technical specification of the latest Raspberry Pi found in the Indonesian market, i.e. Raspberry Pi 4 Computer Model B. Questionnaire was used to reveal the responses of students in receiving the implementation of Raspberry Pi-based bifocal modeling physics practicum and facilities owned by students which may be used to support the implementation of Raspberry Pi-based bifocal modeling physics practicum. Based on the data analysis, it was concluded that: 1) the school facilities are possible to support the implementation of Raspberry Pi-based bifocal modeling physics practicum in terms of facilities due to the computer modeling/ digital part of bifocal modeling physics practicum, 2) most students own smartphones and laptops/ computers which are possible to be utilized as output peripherals for displaying visualized physics phenomena and simulated physics data from Raspberry Pi-based bifocal modeling physics practicum devices, 3) students are willing to accept the implementation of Raspberry Pi-based bifocal modeling physics practicum in physics learning; they consider that such implementation can improve the quality of physics learning, improve the motivation of students to learn physics, and help students to easily understand physics concepts.*

Keywords: *bifocal modeling; physics practicum; raspberry pi*

I. INTRODUCTION

Inquiry-centered laboratory work or practicum is potentially able to improve the quality of science learning. It enables a science learning become meaningful and increases the concept understanding of students. Moreover, inquiry-centered practicum facilitates students with a set of inquiry experiences, by which students can effectively understand the essence of science (Kipnis & Hofstein, 2007).

Inquiry-centered practicum is vital in science learning. It is because the inquiry laboratory activities in that practicum involve students to identify problems, formulate scientific questions and hypothesis, design an experiment, collect and analyzed data, and draw a conclusion (Hofstein & Lunetta, 2004).

Based on the National Science Education Standards (NSES), the term inquiry refers to the description of inquiry as content understanding and inquiry as skill or ability. Inquiry as content understanding enables students to get opportunities to construct concepts and certain scientific patterns as well as give meaning to an idea used to explain what students observe and experience through inquiry processes. Meanwhile, inquiry as skill or ability refers to the abilities of students to identify problems, formulate scientific questions, formulate and revise a scientific explanation, as well as communicate and argue a scientific argumentation (Nivalainen et al., 2013).

Nowadays, there is a tendency for learning to be carried out on the basis of preparing students with a set of skills called 21st century skills. These skills consist of four main groups, i.e. skills resulted from ways of thinking, ways of working, tools for working, and skills for living. Ways of working involve creativity and innovation, critical thinking, problem solving, decision making, as well as learning to learn and metacognition. Ways of working involve communication and collaboration. Tools for working involve information literacy and digital/ ICT literacy. Meanwhile, skills for living involve ways on how students can proceed life normally as a citizen having personal and social responsibilities, including cultural awareness (Wilson et al., 2015).

Indonesian human resources are expected to have specific 21st century skills acquired from learning. The skills consist of critical thinking and problem solving skills, communication and collaboration skills, creativity and innovation skills, ICT literacy, contextual learning skills, and information and media literacy skills (BSNP, 2010).

Physics learning as part of education system in Indonesia is expected to play role in giving positive contribution to preparing students with both scientific knowledge and 21st century skills. It means that through physics learning, students are expected to obtain knowledge, experiences, and skills to face the 21st century life. Understanding and experiences of students in physics learning can be built from what they have learnt and how they conduct learning. What students learn in physics learning deals with the essence of physics as a scientific product and ways done by students to learn physics deal with the essence of physics as a scientific process (Wattimena et al., 2014).

A learning method which can be potentially used to give students with both scientific knowledge and 21st century skills is practicum or inquiry-centered laboratory work. Through practicum, students are facilitated to demonstrate basic principles of physics, know various experimental tools and devices, learn on how to conduct an experiment, and develop certain practical skills (Gupta, 2013). Practicum also enables students to understand the essences of science (physics) as well as acquire knowledge, experiences, practical skills, and higher order thinking skills needed to face the 21st century life (Hofstein & Lunetta, 2004).

Inquiry laboratory work or practicum is very important in physics learning. It is because by doing practicum, students are involved in identifying problems, formulating scientific questions that deal with a physics phenomenon, formulating hypotheses, designing experiment, collecting and analyzing data, and drawing conclusions (Hofstein & Lunetta, 1982). Inquiry laboratory work can also improve the concept understanding, procedural knowledge, and abilities of students in conducting scientific.

Although physics practicum can create physics learning become more meaningful and potentially improve the concept understanding of students as well as give students with skills and attitudes needed to face the 21st century life, its implementation has not been optimal. Several studies revealed that the implementation of practicum at schools faces various barriers, such as the limitation of practicum facilities and the absence of laboratory room and laboratory assistant (Katili et al., 2013). Poor implementation of practicum in senior high schools also deals with the limitation of laboratory kits, tools, and measuring devices (Putri et al., 2014).

One of studies conducted in Bandung District revealed that physics learning that implements practicum method is rarely conducted. It deals with various barriers faced by teachers due to the limitations of physics practicum equipment and the limitations of time dealing with the achievement of curriculum targets. As a result, students finds difficulties to understand some physics concepts because they do not have enough opportunity to observe the physics phenomena in a laboratory (Sunardi et al., 2022).

The problems related to the practicum implementation in senior high schools is getting worse for theoretical, mathematical, and abstract physics concepts. Students have no sufficient opportunities to observe phenomena that deal with such concepts, so the concept understanding and creative thinking skills of students are relatively low (Hermansyah et al., 2015). An example of the theoretical, mathematical, and abstract physics concepts is the theory of kinetic of gases. This concept is mainly taught by lecture method, in which students are given a set of mathematical physics problems. The physics students' understanding of concepts of theory kinetic of gases was relatively low

(Agustina et al., 2018). Incomplete practicum tools and materials in every school should be overcome and practicum programs in every school should be renewed (Shaqinah et al., 2021).

The problems of physics learning, especially those which related to the physics practicum as aforementioned above should be overcome. In this case, rapid development of information and communication technology (ICT) can be potentially utilized to solve such problems. The applications of ICT, including computer and digital learning technology has proven to give positive contribution to facilitate students in developing problem-solving abilities. They can also trigger critical, creative, and innovative ideas in physics learning (Ma'ruf et al., 2020). Moreover, ICT and computational science and engineering (CSE) technology can be used to solve physics learning problems, including those which are related to implementation of physics practicum.

The influence of rapid development of ICT in education is unavoidable in the current era of globalization. Global demands require education sector to always adapt the development of ICT in improving the quality of education. It can be done by adjusting the use of ICT in education, especially in the learning process (Ma'ruf et al., 2021).

ICT and CSE technology can be integrated into a learning method, by which students are able to conduct project-based scientific activities and visualize theoretical, mathematical, and abstract concepts, so the quality of learning can be improved (Vieira et al., 2018). The use of internet of things technology in learning can give positive impacts in improving the students' understanding due to a certain concept (Muchlis et al., 2018). The technology is also able to be used in designing learning, in which students can observe microscopic and abstract phenomena, interact with a computer/ digital model, find a scientific model, and compare the experimental data to simulated data, so students can develop a critical perspective of scientific models. This kind of learning design can be well organized in a bifocal modeling-based physics practicum. The implementation of such practicum has been proven to improve both content and meta-modeling knowledge as well as critical thinking of students. Adoption of bifocal modeling framework in science learning enables students to answer questions about how and why scientific models are used. Students can also identify the strengths and limitations of scientific models (Fuhrmann et al., 2018).

Because, adoption of bifocal modeling framework in physics learning can potentially solve problems of physics learning, especially those dealing with physics practicum, then the potential use of bifocal modeling framework in physics learning should be thoroughly investigated. One of investigation focuses of the adoption of bifocal modeling framework may be oriented to get overviews required for developing a design of bifocal modeling-based physics practicum. As sensor device is one of main parts of bifocal modeling-based tools, the study of this sensor device is needed. A micro-controller hardware potentially used to develop the sensor device is Raspberry Pi. Hence, this research was oriented to reveal profiles of facilities and students' responses in supporting implementation of Raspberry Pi-based bifocal modeling physics practicum in senior high school. The results of this research may be beneficial for giving consideration for other researchers in conducting the next advanced studies.

II. METHODS

This research was a qualitative case study. The case study offers advantages, namely it can achieve high potential validity, has strong procedures to raise new hypotheses, be useful to examine the hypothesized role of causal mechanisms in the context of individual cases, and has capacity to address causal complexity in a specific context (Starman, 2013). The subjects of this research were two physics teachers and seventy-nine students enrolled in classes 10, 11, and 12 at a senior high school in Bandung District in academic year of 2020/ 2021.

The data collection in this research was conducted through interviews, questionnaire, and observation. Interviews done with physics teachers and observation focused on gathering information of school facilities which may be used to support implementation of Raspberry Pi-based bifocal modeling physics practicum. Meanwhile, questionnaire was oriented to students for revealing the students' responses due to the implementation of Raspberry Pi-based bifocal modeling physics practicum. The questionnaire was also used to gather information due to the facilities owned by students that may support the implementation of Raspberry Pi-based bifocal modeling physics practicum.

The data collected through interviews and observation focused on data which deals with the facilities that meet the Raspberry Pi technical specifications compared to the criteria of bifocal modeling framework. The data was then analyzed and presented qualitatively. The data collected through questionnaire was analyzed quantitatively and described in qualitative narration.

III. RESULTS AND DISCUSSION

The results of this study are classified into: 1) results due to school facilities which may support the implementation of Raspberry Pi-based bifocal modeling practicum, 2) results which deal with students' responses due to the implementation of Raspberry-based bifocal modeling practicum and facilities owned by student which support the implementation of Raspberry Pi-based bifocal modeling practicum. These results are shown below. However, for giving meaningful insight the results of this research will be preceded by the texts about bifocal modeling framework and Raspberry Pi.

Bifocal Modeling Framework

Bifocal modeling framework (BMF) is an approach of science learning based on inquiry leaning approach. BMF implementation in a science learning enables students to design, compare, and examine the relationships between real experiment and computer models. Using BMF in learning students are potentially involved in doing main activities, namely formulating questions related to a phenomenon under investigation, generate hypotheses and design physical (real) experiment as well as computer model to be used in conjunction by a sensor device with the real experiment; determining the nature of phenomenon under investigation and construct apparatuses for both real experiment and computer model; and collecting data from the real experiment and from simulated data visualized on a given displaying hardware (Fuhrmann et al., 2018). Bifocal modeling framework (BMF) is illustrated in Figure 1.

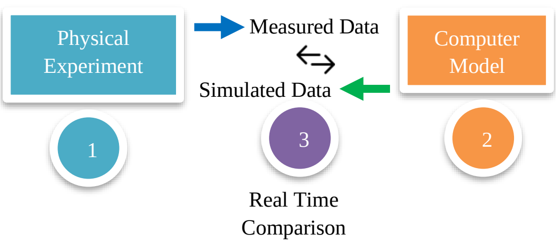

Figure 1. Bifocal Modeling Framework

Purposes of implementing bifocal modeling framework in a science learning is to facilitate students to compare the data gathered from a certain real experiment to the simulated data obtained from a simulated/ computerized model. It is expected to allow students to establish for themselves the value, relevance, and limitations of theoretical modeling within empirical research. In practice, bifocal modeling activities may use different tools and techniques as well as different modes of classroom facilitation. To a certain extent, designers and teachers might combine differently real and virtual experimental setups by using ready-made or student-designed models (Blikstein, 2014). Bifocal modeling framework can be adapted in such a way depending on the characteristics of the phenomenon under investigation. It may use different computer languages, computer hardware, and sensor devices.

Raspberry Pi

Most simulations in science learning are designed without connection to a real (physical) phenomenon. Real-time model validation by implementing sensor technology is challenging. Connecting a physical world with a computer model need a sensor-based technological platform (Blikstein, 2014). Raspberry Pi is a computer technology which can be used as an interface to connect physical phenomena and digital (computer) technology (Richardson & Wallace, 2012).

Raspberry Pi is a single-board circuit which can be utilized to operate a given program or software that can be displayed on a computer monitor both offline and online (Richardson and Wallace, 2012; Zhao et al., 2015). Raspberry Pi can be operated by using computer software developed by programming languages, such as Scratch, Python, C, Ruby, Java, and Perl. A Raspberry Pi board consists of main parts, i.e. processor, HDMI connector, power input, SD card port, status LED, USB port, analog audio ouput, ethernet port, and composite video output. It is shown in Figure 1 (Richardson & Wallace, 2012).

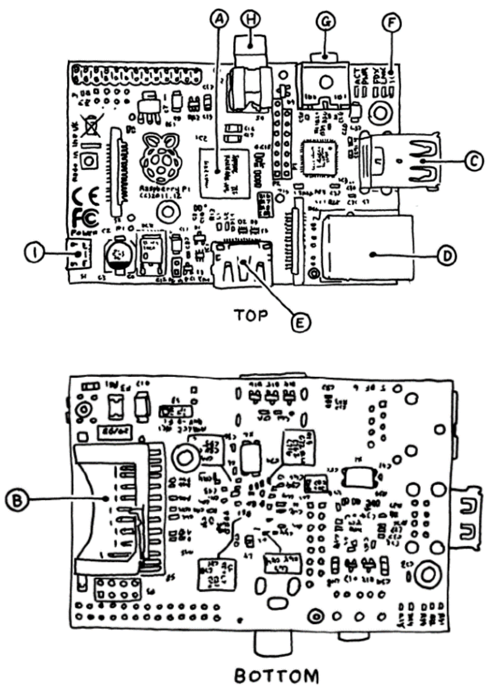

Figure 2. Parts of Raspberry Pi

The potential use of Raspberry Pi as a part of bifocal modeling-based device is based on some reasons as follows. It can be utilized to plug-in to various input and output peripherals, such as computer monitor, television, keyboard, mouse, and pen-drive. Raspberry Pi enable users to develop and design animation, game, and videos by using Phyton programming language. Raspberry Pi can be used to integrate with many components, such as speakers, LED lights, sensors, cameras, and wireless communication units (Zhao et al., 2015).

Various sensor modules which can be operated by using Raspberry Pi among others are sensors of temperature, humidity, gas pressure, motion, wireless, infrared, Bluetooth, electricity, and electric voltage (Jolles, 2021; Zhao et al., 2015; Banerjee et al., 2013).

Raspberry Pi is available in several models. The newest model is Raspberry Pi 4 Computer Model B. Based on the information found in the Raspberry official website (https://www.raspberrypi.com/products/raspberry-pi-4-model-b/specifications/), technical specifications of Raspberry Pi 4 Computer Model B related to the facilities potentially supporting the implementation of Raspberry Pi-based bifocal modeling physics practicum are as follows.

Raspberry Pi 4 Computer Model B has system on chip of Broadcom BCM2711 Cortex-A72 64 Bit Soc @ 1.5 GHz system, graphics processing units of videocore VI @ 500 MHz, random access memory (RAM) of 1GB/2GB/4GB LPDDR42 RAM, storage of microSD, USB ports of 2 × 2.0 USB Ports and 2 × 3.0 USB ports, maximum power of 3 A @5V DC (via USB-C connector or via GPIO header), general purpose input output (GPIO) of 40 pins, gigabit ethernet, bluetooth 5.0, Wifi of dual-band 2.4 GHz and 50 GHz IEEE 802.11 b/g/n/ac wireless lan, and video out of 2×micro HDMI ports (up to 4K).

Raspberry pi can be used to build learning media using animation and virtual reality technology, in which devices, especially a set of personal computers (PCs) and laptops are needed (Wicaksono et al., 2020). Output of Raspberry pi devices can be accessed by any output peripherals, such as computers, laptops, mobile phones, etc (Anandhalli & Baligar, 2018). Based on the Raspberry specifications above, supporting facilities to implement Raspberry Pi-based bifocal modeling physics practicum, especially facilities focused on the digital/ computer model of bifocal modeling devices, may consist of computer equipment, such laptop, personal computer set, mouse, and keyboard; USB cables (one of them must be USB cable type C), HDMI cables; Wifi facilities; 3V DC power supply; and android smartphone equipped with application of VNC (virtual computing network) available on Google Play Store.

Results Due to School Facilities

The objects of school facilities observation in this research were laboratory room, laboratory equipment, and internet facilities. One of observation activities is shown in Figure 3.

Figure 3. Laboratory observation

The results of observation are summarized into four parts, i.e. 1) laboratory room observation, from which it was revealed that there is a laboratory functioned as physics, chemistry, and biology laboratory; laboratory management is done by science teachers without laboratory assistant; the area of the laboratory is about 30 m^2; 2) laboratory facilities observation, from which it was revealed that there are laboratory kits, tools, measuring devices, such as kits of mechanics, thermodynamics, optics, electricity, magnet, temperature and heat. The need of electricity for laboratory operation is supplied by a 2,200 VA electricity source shared with several classrooms; 3) computer laboratory observation, from which it was revealed that there is computer laboratory having 25 personal computers equipped with keyboards and mouses, 1 printer, LAN system, various cable connectors, such as USB and HDMI cable connectors, USB Wifi wireless adapter; 4) internet facilities observation, from which it was revealed that there is internet connection transmitted by 3 Wifi transmitter modules which can be accessed from every area of the school.

The results of observation were compared to the information obtained from interviews with physics teachers. According to teachers, facilities in the observed school are relatively good. Every student can utilize the facilities based on the teachers' guidance. However, teachers could not make sure that all facilities found in that school can meet the requirements of Raspberry Pi-based bifocal modeling physics practicum implementation. It is because they haven't seen the physical of the Raspberry Pi-based bifocal modeling device even they were able to imagine it based on the researcher's explanation done before carrying out interviews. However, teachers were enthusiastic to implement such practicum device in the future.

Personal computer, camera, USB, Ethernet, audio, and Wi-Fi devices can be adapted to the systems (Jolles, 2021). Raspberry Pi can be used to integrate with many components such as speakers, LED lights, sensors, cameras and wireless communication units to develop smart applications. A Raspberry-based device can be operated by several devices, such as laptop (Zhao et al., 2015). Based on the results of observation and interviews with physics teachers compared to the technical specifications of Raspberry Pi, it can be said that the school facilities are possible to support the implementation of Raspberry Pi-based bifocal modeling physics practicum.

Results Due to Students' Responses and Facilities

Students' responses dealing with the implementation of Raspberry Pi-based bifocal modeling practicum and facilities owned by students which may support the implementation of Raspberry Pi-based bifocal modeling practicum were revealed by using questionnaire. The questionnaire consists of fourteen questions (statements) preceded by a brief explanation of bifocal modeling framework and Raspberry Pi.

Students participated in filling out the questionnaire were seventy-nine. It is presented in Table 1 below.

Table 1. Student responses due to implementation of Raspberry Pi-based bifocal modeling practicum

Questions	**Responses (%)**	
	Agree	**Disagree**
Physics practicum helps students to better understand physics concepts.	100	0
Physics practicum help students to bring up the curiosity to a certain natural phenomenon.	84.81	15.19
I can be more motivated to learn physics when teachers organize the learning using practicum method.	92.6	7.4
Computer visualization helps me understand a certain physics concept.	100	0
Combining real experiment with simulated (virtual) experiment can make me obtain holistic understanding of a given physics concept.	97.47	2.53
I have read the explanation due to bifocal modeling practicum & Raspberry Pi and understand that explanation.	84.81	15.19
The use of Raspberry Pi-based device as a part of bifocal modeling practicum tools will make physics learning become more qualified.	100	0

The use of Raspberry Pi-based device as a part of bifocal modeling practicum tools potentially enables students become more motivated in learning physics.	84.81	15.19
The use of Raspberry Pi-based device as a part of bifocal modeling practicum tools potentially enables students become more-easy to understand physics concepts.	92.6	7.4
Students are willing to accept the implementation of Raspberry-based bifocal modeling physics practicum in physics learning.	100	0

The ten statements above are found in the first part of questionnaire used to obtain information dealing with the responses of students in accepting the implementation of Raspberry Pi-based bifocal modeling practicum. Based on the analysis of this part of questionnaire results, it can be seen that students have curiosity to a physics phenomenon when physics learning is done by practicum. Through practicum, students can understand physics concepts and be motivated to learn physics. The use of computer visualization also helps students to better understand physics concepts. Students consider that the combination of real and virtual experiments enables them to obtain holistic understanding of physics concepts. Students also consider that the implementation of Raspberry Pi-based bifocal modeling physics practicum can improve the quality of physics learning, improve the motivation of students to learn physics, and help students to easily understand physics concepts. Hence, students are willing to accept the implementation of Raspberry-based bifocal modeling physics practicum in physics learning.

Meanwhile, the second part of questionnaire in this research consisted of four statements. The responses of this questionnaire is presented in Table 2.

Table 2. Responses Of This Questionnaire

Questions	**Responses (%)**	
	Agree	**Disagree**
I have smartphone having Wi-Fi connection system which enables other wireless device to connect with.	100	0
I have laptop/ computer having Wi-Fi connection system which enables other wireless device to connect with.	50.63	49.37
I can operate my smartphone in various ways, including connecting it to internet or other network systems as well as downloading an application available on Google Play Store.	100	0
I can operate my laptop/ computer in various ways, including connecting it to internet or other network systems.	84.81	15.19

Based on the analysis of the results of second part of questionnaire above, it can be seen that all students have smartphone enabling Wi-Fi connection system which enables other wireless device to connect with. Raspberry Pi systems are highly adaptable as both computer software and hardware and they are easily updated. They can be operated by using personal computer or laptop and be adapted to various devices, such as camera, USB, ethernet, audio system, speakers, LED lights, sensors, cameras and wireless communication units to develop smart applications (Zhao et al., 2015; Jolles, 2021). About fifty percent of students also have laptop/ computer having Wi-fi connection system. Students can operate their smartphone and laptop/computer.

Smartphones and laptops/ computers owned by students can be part of facilities needed to implement Raspberry-based bifocal modeling physics practicum in physics learning. Those two types of devices can be output peripherals for displaying visualized physics phenomena and simulated physics data.

IV. CONCLUSION AND SUGGESTION

Based on the analysis of the research data, it can be concluded that the school facilities are possible to support the implementation of Raspberry Pi-based bifocal modeling physics practicum in terms of facilities due to the computer modeling/ digital part of bifocal modeling physics practicum. Most students own smartphones and laptops/ computers which are possible to be utilized as output peripherals for displaying visualized physics phenomena and simulated physics data from Raspberry Pi-based bifocal modeling physics practicum devices and they are willing to accept the implementation of Raspberry Pi-based bifocal modeling physics practicum in physics learning, they consider that such implementation can improve the quality of physics learning, improve the motivation of students to learn physics, and help students to easily understand physics concepts.

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